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AN AID IN THE DETERMINATION OF FLOUR STRENGTH

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Commercially, the "strength" of wheaten flour has a fairly well defined meaning. It is synonymous with baking quality and implies capacity to work up well as a dough and give large, spongy, shapely loaves. No more precise definition need be attempted. The loaf itself is the only final criterion. But it is always expensive and often very inconvenient to arrange a baking test at the precise time when evidence as to quality is desired. Millers want to know the strength of separate bulks of wheat before blending in preparation for grinding, and, similarly, to know the quality of the flour from the blend. In neither case is there adequate time for a full baking test. Plant-breeders, seeking to produce new wheats of superior baking quality, meet the quantity rather than the time difficulty. They must select the most promising from a great number of hybrid forms at an early stage of breeding. Otherwise, in a few years, they would be overwhelmed with material. Thus their requirement is some indication of strength when only a few pounds of grain are available.

From both the milling and the scientific sides there have naturally been many attempts to devise some test of strength requiring little material and little time. Some suggested tests have been commercially helpful; some are still in use; some are well known; and some are imparted only as secrets, on payment. As commercial experience and scientific knowledge extend, it becomes more and more certain that no one test will ever measure so complex a character as strength. The many contributory factors will have to be individually studied by specially devised methods. It is important to distinguish between investigational "methods" and the "tests" which seek to estimate strength for commercial purposes by one simple process. All "tests" are inevitably subject to strict

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limitations. They are of value and deserve notice only in measure as these limitations are found out and disclosed. The procedure now to be described is essentially a "test." It must not be regarded as of wide application or fundamental importance. With all other tests made on the "dough" it comes under the natural objection that no account is taken of the effects of panary fermentation and oven heat.

The Principle of the Test

In bread making, carbon dioxide gas is generated by the yeast. This transforms the dough into an aggregation of thin-walled vesicles. If the vesicle walls are sufficiently elastic or distensible to allow the vesicles to reach and maintain a relatively great volume, a large and spongy loaf is formed. Thus, in a crude way, strength or baking quality may be regarded as an expression of the "distensibility" of the dough. The principle of this test is to prepare a thin sheet of dough, distend it into bubble form by air pressure, and measure the pressure at which it bursts. One of the great difficulties of this and all other tests of strength, is to ensure the same conditions of temperature and manipulation in dealing with a number of flours in succession. It was finally decided to evade this difficulty instead of directly overcoming it. Instead of measuring the bursting pressure for the dough from any test flour, a simple comparative procedure is followed. Two doughs are prepared side by side, one from the test flour, the other from some standard flour of known baking quality. They are rolled side by side on the same board, mounted side by side on the distension apparatus described below, and air pressure applied until one of them bursts. Trial has shown that the one which bursts is of the lower strength or baking quality. This basic fact can be accepted only for the flours, named below, which were actually tested. For some other flours it may apply, for some it may not. Flours to which the test applies as an index to baking quality may presumably be regarded as differing among themselves primarily in some feature which is reflected in dough-distensibility. By devising a series of standard flours in a manner to be described, the strength of any unknown flour can be stated as greater than that of one standard and less than that of another. Variations in laboratory temperature and other working conditions, which so greatly upset direct-measurement tests, do not affect this comparative test. The unknown flour is always worked and tested side by side with some standard.

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In applying this general principle many forms of apparatus could be devised. Instead of securing distension by filter-pump exhaustion on one side of the sheet of dough, some form of pressure pump could be used. But the apparatus described appears to possess the merits of simplicity and cheapness and may therefore be recommended as an initial form.

Preparing the Dough

A convenient procedure is:

Place 62 grams of a standard flour in an 8-inch porcelain dish and an equal weight of the flour to be tested in another, similar dish (tests based on 31 grams of flour have proved quite satisfactory).

Add to each dish about 28 cc. of distilled water. The amount of water must depend on the character of the flours to be adjusted to give a dough not too dry for even rolling and not wet enough to stick to the hands or apparatus. It must be the same for the standard and the test flour in every comparison.¹

Prepare the dough by stirring with a glass rod and finally making up with the hands, leaving as little flour as possible adhering to the dishes.

Knead the doughs, one with the right, the other with the left hand, and mould them to a spherical form. Then place them side by side on a pastry board and roll them into flat sheets.

A strip of 3-ply wood, 1.0 inch wide and 0.2 inch thick is fastened along each of the shorter sides on the upper surface of the board. The rolling pin, bearing on these strips, presses the doughs out to a uniform thickness. A rolling pin of sufficient weight to flatten the doughs without pressure from the manipulator must be used, for applied pressure is bound to be variable. A piece of engine shafting 2.0 inches long and 1.5 inches in diameter and weighing 12 pounds makes a suitable rolling pin.²

After being rolled flat the doughs should be turned through 90° and rolled again. It will be observed that when rolling is dis-

¹ If the percentage of contained water differs greatly between the standard and the test flour, determination of the water content may have to be made and the added water adjusted to ensure that both doughs have the same water content.

An alternative method of work is to make up both doughs to a "suitable consistency," as judged by feel. This opens up questions too large to be discussed here and which turn largely on the classes of flour under test.

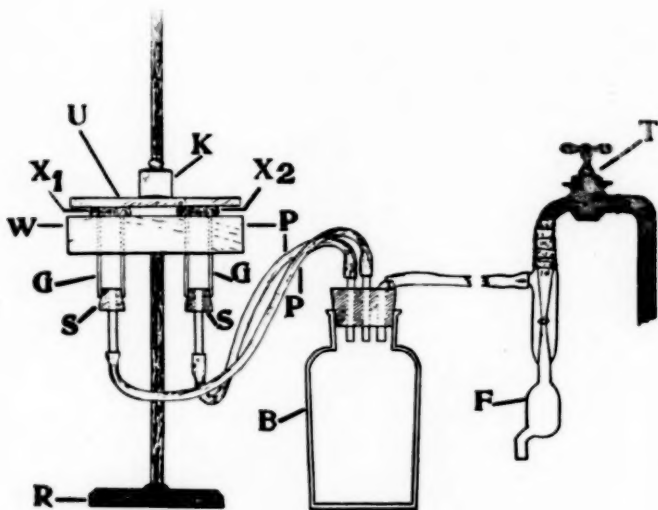
² Errors may arise from distortion of the board by warping. A better, though slightly more costly arrangement for rolling, may be used. In place of the board use a sheet of plate glass mounted in wood. Instead of securing uniform thickness of the doughs by strips along the sides of the board (or glass) mount on the rolling pin two freely moving rings of 0.2 inch thickness. These revolve and act as runners as the rolling pin is moved to and fro.

continued the doughs thicken by a creeping movement. A pause of three minutes should be allowed for this movement before proceeding to the next stage. The rate and amount of this thickening is one of the many ancillary indications of relative strength, which in this test, as in baking, should be carefully heeded.

Next cut from each dough a circular disc by placing on it a crucible 2.25 inches in diameter³ and cutting round with a knife. Roll these discs with the pin, turn them over and roll again, and after a three-minute pause, place them on the distension apparatus about to be described.

The Apparatus

From the diagram the full detail of structure is readily apparent. Clamped to the retort stand, R, is a piece of wood, W (6.5x3.75x1.25 inches. In this are fixed two glass tubes, G, internal diameter 0.8 inch). Through the rubber stoppers, S, which close these tubes, are pieces of glass tubing attached to rubber pressure-tubing, P. The P tubes enter a wide-mouthed bottle, B, to which is also connected by pressure-tubing the filter pump, F, attached to an ordinary water-tap, T.



The doughs, X_1 and X_2 , prepared as above directed, the one from a standard flour, the other from the flour to be observed, are placed upon W symmetrically above the ends of the tubes G.

³ A better device is a brass tube of $2\frac{1}{4}$ inches internal diameter and with the lower end sharpened as in an ordinary cartridge-wad cutter.

Upon them is set a piece of wood, U, which fits exactly above W and in which are two holes corresponding to the upper ends of the tubes G. A 100-gram weight, K, placed upon U, serves to prevent movement at the edges of the dough discs during distension.

Tap T is turned on so as to secure such a steady diminution of pressure within the system as to ensure an even distension of the dough discs. These are forced downward into bubble form until one of them bursts. As soon as this happens each dough-disc is rekneaded with the bulk of dough from which it was cut. Then after rerolling, etc., the procedure is repeated. Which dough bursts is the only observation to be made, although the precise movements of distension are of some interest.

It is desirable to keep the standard dough on, say, the left hand G tube for the first six bursts, rekneading it in the left hand and placing it on the left of the board in rolling. For the next six bursts it is given the right-hand positions and then changed again.

Of many intricacies experience with the method discovers, two must be mentioned. Pressure during kneading markedly affects distensibility, as simply devised tests readily show. On this account care is needed to make the pressure exercised by the two hands—one dough being kneaded in each hand—as even as possible. If two people jointly perform the test, handling one dough each, the same difficulty arises. And there is the important question of hand temperature which, as one experience demonstrated, is not the same for all individuals. A second point of importance is equality in the G tubes, their stoppers, and the P tubes attached to them. At first the G tubes were joined to a T-piece inserted in the stopper of B. A control test was made with X_1 and X_2 , both prepared from the same bulk of flour. Without exception the burst occurred on the left-hand G tube. The cause of this proved to be a slight inequality in the diameters of the arms of the T piece at their junction with the stem. If the G tubes and their attachments are equal in all respects, about equal numbers of bursts should be obtained on the right- and left-hand G tubes with X_1 and X_2 prepared from the same bulk of flour. Before employing the apparatus this control test must be carefully made.

The wide-mouthed bottle, B, besides being a convenient connection, adds to the volume of air upon which the filter-pump acts, and so lessens the irregularities in pressure brought about by uneven flow of water from the tap, T.

The Results

Generally speaking, if the test flour were of lower baking quality than the standard, it was found to burst in the side-by-side comparisons. But exceptions to this occurred in the first few bursts with flours that differed little in strength. Moreover, it has not been possible to test a great range of flour types. Thus it is necessary to give, with some care, an account of the actual results. That classes of flour will be found for which this test is inappropriate is to be expected.

The first series of tests was with Vernon's C C C, a local "bakers" flour, and a locally milled Yeoman flour. These three had been baked on a considerable scale. Their order of baking quality was that in which they have been named. When tested in pairs with the apparatus, the bursts also indicated this order without exception.

Next a series of mixtures of C C C and Yeoman were made. The mixture $\frac{1}{2}$ C C C + $\frac{1}{2}$ Yeoman always burst when tested with pure C C C. With the mixture $\frac{3}{4}$ C C C + $\frac{1}{4}$ Yeoman tested against pure C C C, an exception occurred at the first burst but at all the remaining ten bursts it was the mixture which burst. In other cases exceptions occurred, for example, at the first and third repetitions, the bursts thereafter being in accordance with the known baking qualities. Possibly the irregularities in the first few bursts were connected with differences in fineness of the flours. Finally a series of mixtures differing by steps of $\frac{1}{8}$ was made up from C C C and Yeoman flours and tested, e.g., $\frac{1}{8}$ + $\frac{7}{8}$ against $\frac{8}{8}$; $\frac{2}{8}$ + $\frac{6}{8}$ against $\frac{1}{8}$ + $\frac{7}{8}$, and so on. Various repetitions upon these mixtures over several weeks showed that order of bursting was, for this material, an index to baking quality. In some cases exceptions occurred in the early bursts. As many as eighteen repetitions could be made before the dough became too dry for rolling and distension. Thus there was a good succession of concordant bursts on which to base judgment.

Four other flours were similarly tested and the same agreement was found between the indications of the test and what was known of the respective baking qualities.

To test the sensitiveness of the apparatus, further trials were made upon mixtures of Yeoman and C C C in 1/10 gradations. Their results fully supported the reliability of the test so far as these particular flours were concerned. Thus it may be said that the test is capable of discriminating ten gradations between the

strengths of Yeoman and C C C flours. The precise results for one such test illustrate the irregularities sometimes found in the earlier bursts and the method of recording bursts which has been found convenient. The mixtures, denoted by M_1 and M_2 were:

$$M_1 = \frac{2}{10} C C C + \frac{8}{10} \text{Yeoman}$$

$$M_2 = \frac{3}{10} C C C + \frac{7}{10} \text{Yeoman}$$

In the table of results, R implies that the dough was placed on the right-hand tube (G in figure) and L on the left; while x implies a burst. The results of sixteen bursts in succession were:

M_1 Lx L L Lx Lx Lx Lx Lx Lx Rx Rx Rx Rx Rx Rx
 M_2 R Rx Rx R R R R R R L L L L L L

Yeoman is the weaker flour and thus, disregarding the initial exceptions at the second and third bursts, the result is in accordance with expectation based on what is known of the baking qualities. Many other tests between the 1/10 gradation mixtures were made at various dates. All confirmed the working principle which has been enunciated.⁴

Use in Plant-Breeding

As already explained, the many hybrid forms resulting from cross-breeding, must be reduced in number at early breeding stages. By the time 2 to 3 pounds of grain of each new form has been grown, information on baking quality is desirable. The one conclusive test—by actual baking—cannot be made on 2 to 3 pounds of grain. Moreover, a few ounces of grain must be reserved for propagation. Finally, there are no facilities for the milling of very small bulks of grain. By using the apparatus already described, a procedure can be devised to cope with these difficulties. It may be presented in the form of an account of actual investigation.

Two wheats, Yeoman and Little Joss, were ground in an electric mill⁵ and the meal was sifted by hand through a No. 10 silk stretched on a wooden frame. The flour thus obtained represented only a 30% extraction. But as for this test 62.0 grams of flour suffice for one comparison, tests could readily be based on a 3-pound sample of grain. In direct comparisons between Yeoman and Little

⁴ Subsequent tests have encouraged the belief that the method deserves further study as a quick arbitrary test. It has been successfully applied to a considerable number of biscuit flours in which the criterion of excellence is entirely different from what is sought in bread flours.

⁵ A simple grinding mill made by Lambert, London.

Joss, the latter was always the one to burst, there being no exceptions. Thus the general principle is in harmony with what is known of the baking qualities of these two wheats, Yeoman being the stronger.

By regrinding the residue twice over, a 60% extraction was obtained. Even this is far too low to correspond with commercial milling. All that was sought from tests on these rough grindings was a first indication of quality. As a fact, a test of this kind served to indicate the low quality, later confirmed by baking, of a curious Korean wheat of excellent appearance and relatively high nitrogen content. A number of millers had, on eye-judgment, classed this wheat as of high quality.

In a manner similar to that already explained, 1/10 gradational mixtures were next tested. The results may be expressed by saying that the test is able to discriminate ten gradations between the strengths of Yeoman and Little Joss wheats. Possibly twelve or fifteen gradations between these limits might not prove beyond the sensitiveness of the apparatus. But great sensitiveness is not required in estimating relative baking qualities for breeding and selection purposes. It is proposed to adopt three or four well known wheats as standards, and simply to determine the strength of new hybrid forms as lying, say, half-way between two familiar standards. In this way the test may afford a guide in breeding but, naturally, the ultimate test of finally selected forms will have to be by actual baking. Complementary tests of nitrogen percentage and diastatic capacity will be made on all wheats submitted to the distension test.

An Alternative Form of Test

In its original form the apparatus had only one of the G tubes, (figure). A mercury manometer was included in the system, being connected to the bottle, B. Doughs were prepared from different flours, one at a time, and the pressure at bursting was read on the manometer. The difficulties of ensuring the same conditions of temperature and other influences during observations upon different flours, proved impracticably great. For that reason the direct side-by-side bursting comparison already described was adopted. But readings of bursting pressure were of sufficient interest to be briefly noticed. For a dough from any one flour distended, remade, and again distended a number of times in succession, the bursting pressure was found to have a fairly definite

sequence of values. After a steady rise, there was a constant maximum, and then a fall. Strong flours showed a gradual rise, a high, long-maintained constant maximum, and then a general fall. Weak flours were characterized by rapid rise to a lower constant maximum which was not long maintained. In these features there appeared to be possible indications of some of the characteristics on which baking quality depends. But general tendencies were much disturbed by irregularities in bursting pressure value. Possibly, with modifications, this earlier procedure may prove of some commercial or investigational value. Its use serves, at any rate, to make clear the effects on dough distensibility of temperature, kneading pressure, etc. Among interesting modifications are those in the size of aperture of the tube G, and the thickness to which the dough is rolled. To enter into possible modifications, or the theories by which their effects might be explained, is beyond the purpose of this paper. Actual trial of the apparatus at once opens up a number of intriguing questions. The action of "improvers" or other substances added to flour might, perhaps, be quickly submitted to partial investigation by means of the apparatus.

The fundamental idea used in this test has evidently occurred to a number of investigators. In *Cereal Chemistry* Vol. I, No. 1, C. H. Bailey and Miss Amy M. Le Vesconte have published a paper which includes a translation of a paper by M. Marcel Chopin. Chopin has produced for commercial use an elaborate apparatus for direct measurement of bursting pressure. From the review of methods of test included in the first-mentioned paper, it appears probable that Hankoczy, in 1920, was the first to describe the use of the distension principle.

Summary

The conditions to be fulfilled that Einstein's equation may be applied to the values found for the viscosity of colloidal solutions have been discussed. It was shown that these conditions are not present in measuring the viscosity of acidulated flour suspensions with the MacMichael viscometer. The colloid chemical and hydrodynamical problems arising in the flow of such systems are insufficiently solved at present, so that only empirical equations and rules may be deduced.

THE VISCOSITY OF FLOUR SUSPENSIONS

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Recently, Scott Blair, Watts, and Denham (1927) discussed the theoretical background of the well known empirical relation which Sharp and Gortner (1923) found between the viscosity and the concentration of acidulated flour suspensions. They compared Sharp and Gortner's equation with Einstein's (1906) (1911) formula for the viscosity of colloidal solutions:

$$\eta' = \eta (1 + k\phi)$$

where η' is the viscosity of the colloidal solution, η is the viscosity of the pure solvent, ϕ is the relation between the volume of the colloidal particles and the total volume of the system, and k is a constant which for spherical particles has a value of 2.5.

It is our intention to discuss in this paper the question as to whether or not such a comparison is justified from a theoretical point of view.

In the first place the question arises, does the term "viscosity" in Einstein's equation mean the same principle underlying Sharp and Gortner's equation? Einstein based his equation (deduced theoretically) on the classical definition of the coefficient of viscosity. The coefficient of viscosity in the centimeter, gram, second system may be defined as that force which, when exerted on unit area between two parallel planes of unit area placed one centimeter apart would produce a difference in the velocity of streaming of the two planes of one centimeter per second (cited from Sharp and Gortner, 1923).

Before applying Einstein's theoretical equation to the results of experiments with flour suspensions performed with the MacMichael viscometer, one must determine (1) whether or not the way in which the measurements with the MacMichael viscometer are carried out makes it possible to measure the viscosity as defined above, and (2) whether or not these conditions are also present when working with flour suspensions.

Eimer and Amend, who manufacture the MacMichael viscometer, discuss in detail in their bulletin 280, the sources of error

which attend measurements with this apparatus. Some of the difficulties encountered in the use of this instrument are as follows: the maintenance of a constant temperature, the extension of the outer cylinder beyond the bob, the effect of the bottom of the cup, uncertainty as regards the constancy of the elastic properties of the wires at rather great twistings (as are used in testing flour suspensions), eddy currents in the liquid, etc. One of the conclusions drawn is that "The above more or less contradictory figures seem to show that the instrument in its present form is not adapted to refined scientific investigation of viscosity to the third significant figure." The theoretically deduced conditions are approximated most nearly at small twistings which are read with a mirror and cathetometer. They are most probably not present in the usual method of manipulation in testing flour suspensions, for the wire is frequently twisted as much as 360 degrees. In any case it will be necessary to estimate the magnitude of the errors present in the values before using them in theoretical calculations.

It is known from the colloid chemical literature that satisfactory experimental evidence for the validity of Einstein's equation has not been obtained up to the present time. The conditions for such experimental proof are very difficult to fulfil. In deducing the equation, Einstein assumed the colloidal particles to be rigid and spherical while ϕ should have only a small value. It is possible to satisfy one or two of the above mentioned requirements, but the principal difficulty is that ϕ has a small value only in lyophobic sols in which no, or only a small solvation of colloidal particles is found. But the viscosity of such sols (η') is only slightly higher than that of water (η) and therefore small errors in its determination have a great influence on the value of k . This is seen most easily by writing the equation in the following way:

$$\frac{\eta' - \eta}{\eta} = k\phi$$

It is clear that small variations in η' and η cause great changes in the value of k .

With more viscous colloidal solutions, the difference $\eta' - \eta$ becomes greater, but at the same time ϕ reaches values for which the equation is not valid. Such sols of high viscosity are in general the lyophilic sols, i.e., sols of gelatin, starch, agar-agar, etc. Moreover, the experiments with such colloidal solutions show still an-

other difficulty, that is, their flow does not occur according to the laws premised in the theory of the viscosity of liquids. In many cases a kind of elasticity not found in true liquids is observed, that is, a displacement of one layer of liquid with regard to another, by the action of applied force, is followed by a movement in the opposite direction when the force ceases to act. It is clear that in such a liquid we cannot measure the viscosity in the usual way. Furthermore, in such lyophilic sols aggregates of particles are often formed that prevent motion according to the simple laws of hydraulics. Bungenberg de Jong (1923) found that dilute agar sols showed irregularities when the viscosity was measured below 37° C. (the temperature of gelation); these irregularities disappeared when the measurements were carried out at higher temperatures where no aggregates were present. It is moreover well known that colloidal solutions often show the phenomenon of plastic flow, which is not exhibited by true liquids (for which Einstein deduced his equation).

From the above considerations it is clear that in the acidulated flour suspensions used by Sharp and Gortner, the conditions for the application of Einstein's equation are not fulfilled. Indeed every one who has experimented with such systems knows that comparable results are obtained only if conditions under which the measurements are performed are maintained exactly constant. For example, it is not possible to compare results obtained with different velocities of rotation of the cup of the viscometer. Sharp and Gortner (1923 page 86) have mentioned these facts several times and Sharp (1926) describes in another paper the plastic flow of flour suspensions. The same subject has been discussed by Dunn (1926). Recently Johnson (1927), in an extensive paper, shows once more the various difficulties met in measuring the viscosity of flour suspensions.

In the present state of our knowledge, Sharp and Gortner's formula and method should be considered from the colloid chemical and hydrodynamical point of view as only empirical and arbitrary. In this paper we are not considering the question as to what value the viscosity methods may have for the scientific and routine testing of flour, we wished only to show that looking for a theoretical background as Scott Blair, Watts, and Denham did, can lead to no definite result and that above all a detailed discussion of the electric charge and the hydration of the particles based on the

viscosity measurements done up to this time is premature. It should be made clear that these objections do not apply to the empirical equation proposed by Scott Blair, Watts, and Denham to take the place of Sharp and Gortner's formula, as the exactness of the new equation may be controlled by experiment.

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WHEAT AND FLOUR STUDIES. XII
FACTORS INFLUENCING THE VISCOSITY OF FLOUR-
WATER SUSPENSIONS II. EFFECT OF HYDROGEN-
ION CONCENTRATION DURING EXTRACTION
OR DIGESTION PERIOD.¹

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Introduction

In some of the work done in this laboratory it was noted that flours bleached with chlorine formed water suspensions which, when acidulated, were more viscous than exactly similar suspensions prepared with the same flour unbleached. These flour-water suspensions were prepared according to the method of Gortner (1924). (According to this method the flour is suspended in a liter of distilled water and digested for one hour. After allowing sufficient time for the flour to settle to the bottom of the flask, most of the water is decanted and 500 cc. more water added. Fifteen minutes later the second portion of water is decanted and the residue made up to 100 cc. This suspension is placed in the cup of a MacMichael viscometer and, after acidulation with 0.50 cc. of 20% lactic acid, the viscosity is determined.) In one instance when the extractions were made at 25° C. the viscosity of a flour-water suspension of a patent flour was 155 degrees MacMichael while for the same flour bleached with chlorine the viscosity was 197 degrees MacMichael. When the natural and bleached flours were extracted in like manner at 40° C. the viscosities were correspondingly higher, being 192 and 218 degrees MacMichael respectively.

For several reasons flours bleached with chlorine might be expected to yield more viscous suspensions under these experimental conditions than unbleached flours. Durham (1925) has shown that flour-water suspensions become more viscous when a small quantity of hydrogen peroxide is added to the acidulated suspension. The increase in viscosity which occurs is ascribed to the oxidizing effect of the hydrogen peroxide on the flour protein. As chlorine is an oxidizing agent, it might be expected that it would

¹ Published with the approval of the Director.

function in the same way as hydrogen peroxide. The possibility exists, therefore, that flours bleached with chlorine may yield more viscous suspensions (after acidulation) than natural flours, because some of the protein of the bleached flour has been oxidized to denatured proteins, which exhibit greater imbibitional capacities than the natural wheat proteins.

Another explanation for the higher viscosities of chlorine-bleached flour-water suspensions as compared with those of the same flour unbleached may be that suspensions of bleached flour have higher hydrogen-ion concentrations during their preparation for the viscosity determination. The higher H-ion concentrations of bleached flour suspensions may operate in at least two ways to result in higher viscosities for the final acidulated suspension. The higher H-ion concentration of the bleached flour-water suspension would cause the protein to become more hydrated than protein in the less acid suspension. It may be that this originally greater hydration may make the bleached flour protein susceptible to greater hydration than natural flour protein, when conditions for maximum hydration are made possible.

Bleached flour-water suspensions which are extracted to remove the electrolytes may, for another reason, exhibit higher viscosities than suspensions of the same flour unbleached. The enzyme phytase reacts more rapidly to liberate phosphates in acid media than in alkaline media. The optimum H-ion concentration for the activity of phytase could not be found in the literature. Anderson (1915) states, however, that the activity of the enzyme is most rapid in 0.2% hydrochloric acid solution. While the acidities of natural or bleached flour-water suspensions are a long way from this value, the acidities of suspensions containing bleached flour are nearer to this optimum than those of suspensions containing unbleached flour; hence, more electrolytes should be liberated during digestion of the more acid suspension. If more electrolytes are decanted, the final suspension would contain less of them and have a higher viscosity after acidulation. Johnson (1927) has already shown the operation of this phenomenon when the electrolytes are extracted from flour-water suspensions at different temperatures.

A few preliminary experiments in which acid or alkali was added to the water used for extracting electrolytes from flour suspensions, indicated that the H-ion concentration at which the extraction was made had a marked effect on the viscosity of the final acidulated suspension. As the H-ion concentration of flour ex-

tracts changes during storage, a corresponding change in the viscosity of their suspensions should be anticipated. Also, different grades of flour differ in the H-ion concentration of suspensions containing them. So little was known concerning the effect of the H-ion concentration existing in a suspension during its preparation for the viscosity determination on the final viscosity, that it was decided to make a study of this factor.

Experimental

Viscosity of Acidulated Flour-Water Suspensions Extracted at Different H-ion Concentrations

The flours used in the experimental work were a patent, the same patent bleached with chlorine, a first clear, and a second clear, all milled from the same wheat. Later, in order better to establish the results, another series of flours was obtained. This series consisted of a patent, a first clear, and a second clear. Again all were milled from the same wheat; and a durum flour. Significant data on all these flours are given in Table I.

TABLE I
THE MOISTURE, PROTEIN, AND ASH CONTENTS OF THE SEVERAL FLOURS USED IN THIS STUDY

Flour grade	Table in which data are given	Moisture	Nitrogen	Ash
		%	%	%
Patent natural.....	II	11.25	2.22	0.41
Patent bleached.....	III	11.32	2.22	0.41
First clear.....	IV	10.97	2.53	0.74
Second clear.....	V	11.40	2.64	1.64
Patent.....	VI	12.33	2.13	0.42
First clear.....	VII and XII	11.98	2.44	0.61
Second clear.....	VIII and XIII	11.50	2.40	1.49
Durum.....	IX	12.04	2.17	0.72

The experimental procedure followed in extracting the electrolytes was essentially that of Gortner (1924), using 18-gram portions, suspended in a liter of distilled water. The H-ion concentration of the suspensions was varied by adding the proper quantity of N/14 hydrochloric acid or N/14 sodium hydroxide. The water used in making the suspensions was carefully prepared, being re-distilled and aerated in order to remove all CO₂. As the work of Johnson (1927) has shown that the degree of shaking affected the viscosity, care was taken to shake the suspensions uniformly. Exactly 15 minutes before the wash water was decanted, the liter Erlenmeyer flasks were set at an angle in order that the flour might settle in such a way that it would not be disturbed

during decantation. After decantation of the first liter of wash water, 500 cc. of additional water was added to the precipitate, the flasks were again set at an angle, and exactly 15 minutes later this water was also decanted. The residue in the flask was made up to 100 cc. and after acidulation with 0.50 cc. of 20% lactic acid, its viscosity was determined with a MacMichael viscometer. In all the work, great care was taken to control accurately the time of digestion and to allow the same time for the flour to settle to the bottom of the flask. The nitrogen content of both the 1000-cc. and the 500-cc. decantates was determined. As it was known that flour proteins were dispersed at certain concentrations of the hydrogen or hydroxyl ion, it was hoped that these determinations would indicate when the protein had been dispersed to such an extent that the viscosity would be lowered because of the removal of the protein from the final suspension used for the viscosity determination. Also, the H-ion concentrations of the liter decantates were determined. These determinations were made potentiometrically, using a Leeds and Northrup type K potentiometer, a standardized Weston cell as a source of constant reference potential, a normal calomel half cell, a Bailey (1920a) hydrogen electrode, and a galvanometer as the null point instrument.

The determinations discussed in the preceding paragraph were not made in duplicate. They were, however, made at two different temperatures, 25° and 40° C. It was thought that parallel results would be obtained at these two temperatures or that significant differences would appear. In any case the determinations at the two temperatures were considered of greater value than duplicate determinations. With suspensions extracted at 40° C., only the extraction was made at this temperature, the viscosity after acidulation being determined on the suspension cooled to 25° C.

The data in Tables II to IX show the results. A study of the data in these tables indicates that the addition of acid to the flour-water suspension operated to make the viscosity of the acid-extracted suspension greater than that of the suspension extracted without acid. The addition of alkali, on the other hand, diminishes the viscosity. The H-ion concentrations of the suspensions showing the highest viscosities differed for the different temperatures of extraction. At 25° C. the highest viscosities for the eight flours studied were obtained when the suspensions were extracted at concentrations varying from pH 5.07 to pH 4.34; while for those extracted at 40° C., maximum viscosities were obtained at concen-

trations equivalent to pH values between 4.90 and 5.44. At these concentrations about 50% of the total nitrogen of the flour was found in the decantate except with the second clear flour, in which only 32 to 36% was decanted. As even larger quantities of nitrogen were decanted at higher concentrations, the decrease in viscosity is probably due to decrease in protein in the final suspension used.

TABLE II
VISCOSITIES OF ACIDULATED PATENT FLOUR SUSPENSIONS EXTRACTED AT DIFFERENT H-ION CONCENTRATIONS AND TWO DIFFERENT TEMPERATURES; AND NITROGEN CONTENTS OF THE EXTRACTS

Extracted at 25°C.						
cc. of N/14 acid or al- kali added	pH	Viscosity	Nitrogen extracted			
			1000-cc. extract	500-cc. extract	Total	Total
Alkali		°MacM.	cg.	cg.	cg.	%
9	7.64	96	15.50	3.42	18.92	47.3
8	7.39	89	14.60	3.90	18.50	46.3
7	7.15	83	12.30	2.75	15.05	37.6
6	6.88	90	10.80	3.93	14.73	36.8
5	6.66	100	9.95	4.60	14.55	36.6
4	6.52	125	9.20	3.07	12.27	30.7
3	6.35	125	8.05	3.20	11.25	28.2
2	6.17	139	8.35	3.35	11.70	29.3
1	5.88	157	8.75	3.05	11.80	29.5
0	5.75	155	9.20	3.55	12.75	31.9
Acid						
1	5.56	189	10.70	3.95	14.65	36.6
2	5.34	205	12.80	4.75	17.55	43.9
3	5.15	215	14.30	4.10	18.40	46.0
4	4.93	236	16.70	3.63	20.33	50.9
5	4.77	260	16.90	3.65	20.55	51.5
6	4.63	248	18.45	3.23	21.68	54.3

Extracted at 40°C.						
cc. of N/14 acid or al- kali added	pH	Viscosity	Nitrogen extracted			
			1000-cc. extract	500-cc. extract	Total	Total
Alkali		°MacM.	cg.	cg.	cg.	%
9	7.66	125	16.10	3.93	20.03	50.1
8	7.22	110	13.85	3.63	17.48	43.7
7	7.08	116	11.70	3.65	15.35	38.4
6	6.90	120	11.20	3.75	14.95	37.4
5	6.76	130	10.15	3.90	14.05	35.2
4	6.56	146	9.40	3.20	12.60	31.5
3	6.44	159	8.65	2.60	11.25	28.2
2	6.20	170	8.65	2.75	11.40	28.5
1	6.05	178	9.35	2.85	12.20	30.6
0	5.80	192	10.70	2.95	13.65	34.2
Acid						
1	5.53	236	13.35	3.10	16.45	41.2
2	5.33	223	16.65	3.47	20.12	50.4
3	5.14	237	19.35	3.03	22.38	56.0
4	4.99	258	20.20	3.30	23.50	58.8
5	4.82	208	21.85	3.10	24.95	62.5
6	4.68	...	22.80	2.87	25.67	64.2

As examples of the increases in viscosity which occurred when flours were leached with water containing small quantities of acid, some of the data will be cited. The original viscosity of the patent flour given in Table II was 155 degrees MacMichael, the H-ion concentration of the decantate being equivalent to pH 5.75. As the suspensions were leached at higher concentrations, the resultant viscosities exhibited correspondingly higher values until at a concentration equivalent to pH 4.77, a maximum viscosity of 260 degrees MacMichael was obtained. This is an increase of 105 degrees, or about 60% over the original viscosity. When the extractions were made at higher concentrations than pH 4.77, the final viscosities were lower, probably because more of the protein responsible for viscosity was decanted. In Table III are given data obtained from experiments with the same flour after bleaching with chlorine. These data show that the original viscosity of the bleached flour was notably higher than that of the patent flour. Upon extracting the natural flour at higher H-ion concentrations, its maximum viscosity was found to be just as great as that attainable by bleached flour. It appears, therefore, that only the property of chlorine to increase the H-ion concentration operated to increase the viscosity of suspensions such as these and not its oxidizing properties.

With the second clear flour, the data in Table V show that the viscosity of the acid-digested suspensions increased even more, in proportion to the original viscosity of the flour, than with the patent flour. Thus the original viscosity of the second clear flour was 76 degrees MacMichael, while the viscosity when extracted in suspension of H-ion concentration equivalent to pH 4.39, was 188 degrees MacMichael. This is an increase of 112 degrees, or nearly 150%. The reason for this greater increase in viscosity of the second clear flour may be that at 25° C. only 32% of the protein was dispersed, while for the patent about 50% was dispersed. Even at high concentrations it was not possible to disperse the proteins of the second clear flour in suspension at 25° C. to as great a degree as the patent flour. At 40° C., however, dispersion was greater. This may account for the fact that the maximum viscosity of the flour extracted at 40° C. was lower than that obtained at 25° C., being 188 at 25° C. and 171 at 40° C. In most cases the maximum viscosity obtained at 40° C. was greater than that obtained at 25° C. This is in accordance with observations already published by Johnson (1927).

TABLE III
VISCOSITIES OF ACIDULATED BLEACHED PATENT FLOUR SUSPENSIONS EXTRACTED AT DIFFERENT
H-ION CONCENTRATIONS AND AT TWO DIFFERENT TEMPERATURES;
AND NITROGEN CONTENTS OF THE EXTRACTS

Extracted at 25°C.						
cc. of N/14 acid or al- kali added	pH	Viscosity	Nitrogen extracted			
			1000-cc. extract	500-cc. extract	Total	Total
Alkali		°MacM.	cgm.	cgm.	cgm.	%
9	7.56	111	18.45	2.95	21.40	53.5
8	7.30	109	13.35	2.80	16.15	40.5
7	7.08	103	11.40	2.73	14.13	35.4
6	6.86	100	10.60	3.20	13.80	34.5
5	6.71	115	9.25	2.90	12.15	30.4
4	6.51	139	8.05	3.12	11.17	28.0
3	6.30	152	8.35	3.02	11.37	28.5
2	6.10	164	8.55	3.12	11.67	29.2
1	5.80	185	9.20	4.03	13.23	33.1
0	5.53	197	11.70	3.63	15.33	38.4
Acid						
1	5.32	213	13.50	4.20	17.70	44.3
2	5.09	246	14.25	4.35	18.60	46.5
3	4.88	246	16.10	4.20	20.30	50.8
4	4.73	240	18.50	3.70	22.20	55.5
5	4.58	200	21.00	3.07	24.07	60.2
6	4.34	156	22.85	3.12	25.97	65.0

Extracted at 40°C.						
cc. of N/14 acid or al- kali added	pH	Viscosity	Nitrogen extracted			
			1000-cc. extract	500-cc. extract	Total	Total
Alkali		°MacM.	cgm.	cgm.	cgm.	%
9	7.52	181	14.80	2.85	17.65	44.2
8	7.30	143	13.05	3.15	16.20	40.5
7	7.05	151	11.20	3.23	14.43	36.1
6	6.83	165	10.35	2.85	13.20	33.0
5	6.64	154	9.10	3.47	12.57	31.5
4	6.47	165	8.80	3.00	11.80	29.5
3	6.36	180	8.20	3.02	11.22	28.1
2	6.07	196	10.25	3.12	13.37	33.5
1	5.81	193	11.15	3.10	14.25	35.7
0	5.51	218	13.90	3.23	17.13	42.8
Acid						
1	5.32	261	16.70	3.00	19.70	49.3
2	5.12	241	19.15	3.27	22.42	56.1
3	4.97	218	20.95	3.60	24.55	61.5
4	4.78	172	22.15	3.73	25.88	64.7
5	4.60	118	23.20	4.12	27.32	68.5
6	4.41	...	23.05	3.70	26.75	67.0

TABLE IV
 VISCOSITIES OF ACIDULATED FIRST CLEAR FLOUR SUSPENSIONS EXTRACTED AT DIFFERENT H-ION
 CONCENTRATIONS AND AT TWO DIFFERENT TEMPERATURES; AND
 NITROGEN CONTENTS OF THE EXTRACTS

Extracted at 25°C.						
cc. of N/14 acid or al- kali added	pH	Viscosity	Nitrogen extracted			
			1000-cc. extract	500-cc. extract	Total	Total
Alkali		°MacM.	cg.	cg.	cg.	%
16.0	8.28	161	25.00	2.47	27.47	60.2
14.0	7.86	151	24.00	2.60	26.60	58.3
12.0	7.35	129	19.00	2.70	21.70	47.6
10.0	6.93	105	17.00	4.57	21.57	47.3
8.0	6.69	95	14.15	3.67	18.82	41.2
6.0	6.49	109	11.95	4.35	16.30	35.7
4.5	6.36	124	9.90	3.45	13.35	29.2
3.0	6.27	161	9.10	2.18	11.28	24.7
2.0	6.17	175	9.05	2.43	11.48	25.2
0	6.00	180	9.40	2.30	11.70	25.6
Acid						
2	5.70	208	9.50	3.15	12.65	27.7
4	5.43	234	10.80	3.85	14.65	32.1
6	5.10	213	12.70	4.00	16.70	36.6
8	4.85	240	14.45	3.93	18.38	40.3
10	4.60	245	17.00	3.68	20.68	45.2
12	4.34	255	19.20	3.45	22.65	49.6
15	3.97	220	23.55	2.92	26.47	58.0
18	3.73	148	26.00	2.23	28.23	61.9
21	3.53	118	25.20	2.00	27.20	59.6

Extracted at 40°C.						
cc. of N/14 acid or al- kali added	pH	Viscosity	Nitrogen extracted			
			1000-cc. extract	500-cc. extract	Total	Total
Alkali		°MacM.	cg.	cg.	cg.	%
16.0	7.86	165	23.20	3.45	26.65	58.5
14.0	7.54	152	22.40	3.18	25.58	56.0
12.0	7.27	141	19.00	3.15	22.15	48.5
10.0	7.03	129	16.60	4.30	20.90	45.8
8.0	6.78	143	13.50	2.60	16.10	35.3
6.6	6.57	148	11.40	2.90	14.30	31.3
4.5	6.42	159	9.80	2.85	12.65	27.7
3.0	6.34	176	9.10	2.65	11.75	25.8
2.0	6.24	210	9.40	2.43	11.83	25.9
0	5.90	220	10.40	2.53	12.93	28.3
Acid						
2	5.56	255	12.40	2.53	14.93	32.7
4	5.26	317	16.70	3.08	19.78	43.3
6	4.97	347	19.95	3.15	23.10	50.6
8	4.61	280	24.50	3.43	27.93	61.0
10	4.39	...	26.80	3.78	30.58	67.0
12	4.12	...	26.90	3.45	30.35	66.5

TABLE V

VISCOSITIES OF ACIDULATED SECOND CLEAR FLOUR SUSPENSIONS EXTRACTED AT DIFFERENT H-ION CONCENTRATIONS AND AT TWO DIFFERENT TEMPERATURES; AND NITROGEN CONTENTS OF THE EXTRACTS

Extracted at 25°C.						
cc. of N/14 acid or al- kali added	pH	Viscosity	Nitrogen extracted			
			1000-cc. extract	500-cc. extract	Total	Total
Alkali		°MacM.	cg.	cg.	cg.	%
9	6.85	12	17.55	2.60	20.15	42.3
6	6.62	22	17.20	2.85	20.05	42.1
3	6.37	62	18.60	2.55	21.15	44.4
0	6.20	76	15.35	2.45	17.80	37.4
Acid						
3	5.90	120	12.60	2.60	15.20	31.9
6	5.71	132	11.20	2.15	13.35	28.0
9	5.49	135	10.90	1.95	12.85	27.0
12	5.27	142	11.20	2.15	13.35	28.0
15	5.07	157	12.30	2.60	14.90	31.3
18	4.90	163	11.90	3.45	15.35	32.3
22	4.65	172	12.30	3.18	15.48	32.5
25	4.39	188	11.95	3.50	15.45	32.4
30	4.12	177	11.20	2.22	13.42	28.2
35	3.85	128	10.90	2.65	13.55	28.5
40	3.60	75	10.70	2.55	13.25	27.8
45	3.42	45	10.85	2.23	13.08	27.5
50	3.19	35	11.45	2.00	13.45	28.3

Extracted at 40°C.						
cc. of N/14 acid or al- kali added	pH	Viscosity	Nitrogen extracted			
			1000-cc. extract	500-cc. extract	Total	Total
Alkali		°MacM.	cg.	cg.	cg.	%
6	6.54	48	18.00	2.65	20.65	43.5
3	6.35	77	16.70	3.10	19.80	41.6
0	6.27	97	14.60	3.40	18.00	37.8
Acid						
3	6.10	126	12.90	2.92	15.82	33.2
6	5.91	142	12.40	2.42	14.82	31.1
9	5.68	152	13.40	2.57	15.97	33.6
12	5.41	171	14.70	2.55	17.25	36.2
15	5.09	167	17.00	2.80	19.80	41.6
18	4.82	167	19.35	3.20	22.55	47.4
22	4.38	140	20.85	4.25	25.10	52.7
25	4.21	95	19.35	5.37	24.72	51.9
30	3.90	85	20.05	4.43	24.48	51.3

Most of the data cited were obtained when suspensions were extracted at 25° C. When extracted at 40° C., exactly similar conclusions may be drawn. In this case, however, actual viscosities were higher, as more electrolytes were extracted from the suspension at the higher temperature, a fact which Johnson (1927) has already established. A comparison of the viscosity data in Table II shows that the flour suspensions extracted at 40° C. exhibited higher viscosities than those extracted at 25° C. except at the highest two H-ion concentrations, in which considerably more protein was dispersed thereby causing the low viscosities.

It should also be noted that the addition of equal quantities of acid to flour suspensions, whether maintained at 25° or 40° C., effected approximately the same changes in concentration. This is in accordance with what might be expected from the work of Hoffman and Gortner (1924), whose results indicate that at the H-ion concentrations encountered in this work equal quantities of either acid or alkali effect the same changes in concentration regardless of temperature.

It has already been shown that the viscosities of flour-water suspensions increased when the suspensions were extracted at higher concentrations than those of the original flour. When, on the other hand, small quantities of alkali were added to the water used in extracting flour suspensions, the viscosities of the final acidulated suspensions were lower. Thus in the case of the patent flour suspension (Table II) extracted at 40° C. and at H-ion concentrations equivalent to pH values 5.80, 6.20, 6.56, 6.90, and 7.22, the viscosities were 192, 170, 146, 120, and 110 degrees MacMichael, respectively. Similar decreases in viscosity of the acidulated suspensions occurred with all the flours listed in Tables II to IX, when their suspensions were extracted at increasing hydroxyl-ion concentrations. Just as viscosities of the second clear flour showed the greater increases when they were extracted at higher H-ion concentrations, so they showed relatively greater decreases when extracted at higher concentrations of the hydroxyl-ion.

In a few instances shown in Tables II, III, and IV the viscosities of suspensions extracted at the highest hydroxyl-ion concentration were greater than those of suspensions extracted at lower concentrations (see Table II data for 40° C.). This could not be accounted for as being due to experimental error, hence it was thought that if suspensions were extracted at even higher

TABLE VI
VISCOSITY OF ACIDULATED PATENT FLOUR SUSPENSIONS EXTRACTED AT DIFFERENT H-ION
CONCENTRATIONS AND AT TWO DIFFERENT TEMPERATURES; AND NITROGEN
CONTENT OF THE EXTRACTS

Extracted at 25°C.						
cc. of N/14 acid or al- kali added	pH	Viscosity	Nitrogen extracted			
			1000-cc. extract	500-cc. extract	Total	Total
Alkali		°MacM.	cgm.	cgm.	cgm.	%
24	10.31	0	32.50	4.75	37.25	97.3
21	9.84	3	32.00	4.57	36.57	95.5
18	9.57	13	30.80	5.60	36.40	95.0
15	9.21	79	24.90	3.50	28.40	74.2
12	8.37	106	22.60	2.65	25.25	66.0
9	7.61	93	20.40	2.75	23.15	60.5
6	6.98	86	14.20	3.12	17.32	45.2
5	6.80	83	11.60	2.70	14.30	37.3
4	6.60	96	9.70	2.70	12.40	32.4
3	6.47	112	8.40	2.90	11.30	29.4
2	6.34	126	8.50	2.35	10.85	28.3
1	6.19	141	8.70	2.70	11.40	29.8
0	6.05	163	9.40	3.12	12.52	32.6
Acid						
1	5.71	180	12.30	3.87	16.17	42.2
2	5.39	195	15.40	3.72	19.12	49.9
3	5.20	203	17.20	3.95	21.15	55.2
4	5.07	213	18.30	3.75	22.05	57.6
5	4.82	206	19.70	3.75	23.45	61.2
6	4.67	170	21.95	3.70	25.65	67.0
7	4.50	155	23.90	3.75	27.65	72.2

Extracted at 40°C.						
cc. of N/14 acid or al- kali added	pH	Viscosity	Nitrogen extracted			
			1000-cc. extract	500-cc. extract	Total	Total
Alkali		°MacM.	cgm.	cgm.	cgm.	%
21	9.92	0	32.20	1.50	33.70	88.0
18	9.58	2	31.50	2.55	34.05	88.9
15	9.33	47	27.80	3.07	30.87	80.6
12	8.57	121	22.20	2.65	24.85	64.8
9	7.72	149	17.70	3.30	21.00	54.8
6	7.05	134	12.65	4.22	16.87	44.0
5	6.85	113	10.80	3.30	14.10	36.8
4	6.67	125	9.55	2.95	12.50	32.6
3	6.54	129	8.60	2.65	11.25	29.3
2	6.38	148	8.50	2.65	11.15	29.1
1	6.19	166	8.80	2.85	11.65	30.4
0	6.02	199	10.25	3.20	13.45	35.1
Acid						
1	5.68	210	14.05	3.70	17.75	46.3
2	5.39	239	17.30	3.85	22.15	57.8
3	5.17	225	20.20	3.42	23.62	61.7
4	5.00	215	21.50	3.07	24.57	64.1
5	4.68	155	23.40	3.25	26.65	69.6
6	4.53	...	23.85	3.35	27.25	71.2
..

TABLE VII
 VISCOSITIES OF ACIDULATED FIRST CLEAR FLOUR SUSPENSIONS EXTRACTED AT DIFFERENT H-ION
 CONCENTRATIONS AT TWO DIFFERENT TEMPERATURES; AND NITROGEN
 CONTENT OF THE EXTRACTS

Extracted at 25°C.						
cc. of N/14 acid or al- kali added	pH	Viscosity	Nitrogen extracted			
			1000-cc. extract	500-cc. extract	Total	Total
Alkali		°MacM.	cg.	cg.	cg.	%
31.5	10.29	0	38.25	4.97	43.22	98.4
27	10.11	4	38.10	5.32	43.42	98.9
22.5	9.86	18	33.30	5.15	38.45	87.5
18	9.35	68	28.50	4.12	32.62	74.4
13.5	8.30	123	22.50	2.40	24.90	56.7
9	7.25	78	18.00	2.52	20.52	46.7
4.5	6.71	83	11.55	2.75	14.30	32.5
3	6.54	105	10.00	2.47	12.47	28.4
1.5	6.35	110	9.10	2.50	11.60	26.4
0	6.17	120	9.35	2.25	11.60	26.4
Acid						
1	6.07	137	9.60	2.97	12.57	28.6
2	5.81	145	9.80	2.55	12.35	28.1
4	5.61	170	10.90	3.22	14.12	32.2
7	5.15	190	13.30	3.50	16.80	38.2
9	4.95	208	17.35	4.45	21.80	49.6
10	4.76	216	.....	.....	.....	.....
12	4.48	173	18.70	3.80	22.50	51.2
15	4.17	150	21.15	1.65	22.80	51.9

Extracted at 40°C.						
cc. of N/14 acid or al- kali added	pH	Viscosity	Nitrogen extracted			
			1000-cc. extract	500-cc. extract	Total	Total
Alkali		°MacM.	cg.	cg.	cg.	%
31.5	10.24	0	39.60	2.25	41.85	95.4
27	10.04	0	39.80	3.07	42.87	97.7
22.5	9.77	2	37.60	2.95	40.55	92.5
18	9.38	48	29.50	3.80	33.80	77.0
13.5	8.28	138	23.40	2.60	26.00	59.2
9	7.30	123	18.15	3.72	21.87	49.8
4.5	6.72	105	11.70	3.15	14.85	33.8
3	6.55	122	10.00	2.35	12.35	28.1
1.5	6.37	130	9.90	2.40	12.30	28.0
0	6.17	144	9.95	2.97	12.92	29.4
Acid						
1	6.03	165	10.70	2.70	13.40	30.5
2	5.83	192	12.20	3.17	15.37	35.0
3	5.64	195	13.60	3.47	17.07	38.8
4	5.54	203	15.15	3.35	18.50	42.1
5	5.42	226	17.20	3.90	21.10	48.0
6	5.24	237	18.35	3.90	22.25	50.6
7	5.02	253	20.90	3.92	24.82	56.5
8	4.90	265	22.40	4.20	26.60	60.5
9	4.80	220	21.05	4.90	25.95	59.0

hydroxyl-ion concentrations greater viscosities might result and if this were the case, some explanation might be evolved for the greater viscosity of suspensions prepared by extraction with water containing acid and alkali. It is chiefly for this purpose that the data assembled in Tables VI and VII were accumulated. The flours used in the preceding work were no longer available.

The data in Tables VI and VII indicate that the viscosities of suspensions extracted at decreasing H-ion concentrations decreased quite regularly until a concentration equivalent to pH 8 (app.) was reached. For suspensions extracted at approximately this concentration, a definite increase in viscosity occurred after acidulation. This took place in both the patent and the first clear flours whether extracted at 25° or 40° C.

This phenomenon indicates that at least two factors are responsible for the swelling of the flour proteins when water suspensions of them were acidulated: (1) the electrolytes present in the suspension; and (2) the susceptibility of the protein to maximum imbibition when the acidulation with 20% lactic acid occurs. The greater viscosities of the suspensions extracted at pH 8 were probably due to the operation of the second of these factors. The proteins were partially swollen at this concentration and when conditions for maximum hydration were made favorable, their exposure to the alkali had rendered them susceptible to greater imbibition than if not already partially swollen. The chief reason for this belief was that when extraction was made at hydroxyl-ion concentrations slightly greater than those at which maximum viscosities on alkaline side were obtained, the viscosities fell off extremely rapidly, owing to more complete dispersion of the protein, as the data on the nitrogen extracted will indicate. This dispersion is, no doubt, due to a swelling of the protein, and as it took place so readily, immediately after the viscosities increased, there is reason to believe that it was beginning to occur at the point where the viscosity increased. As the proteins were dispersed in a similar manner when suspensions were extracted at increasing H-ion concentrations, it is likely that at some concentration on the acid side, also, the undispersed protein became more susceptible to greater imbibition when the final suspension was acidulated with lactic acid. On the acid side, however, it is difficult to determine the point where the concentration was such as to make the proteins susceptible to greater hydration, as at increasing concentrations two factors were operating to increase the hydration capacity, while at increasing concentrations of the hydroxyl-ion the

effect of one factor opposed that of the other. Thus, by exposure to certain increasing concentrations of both the hydrogen and the hydroxyl ion, the flour proteins were rendered capable of greater hydration; moreover, exposure to increasing concentrations of the hydrogen ion resulted in extracting greater quantities of the electrolytes, again favoring greater hydration by the proteins; while exposure to increasing concentrations of the hydroxyl-ion resulted in the extraction of smaller and smaller quantities of electrolytes, a factor which opposed hydration.

TABLE VIII
VISCOSITIES OF ACIDULATED SECOND CLEAR FLOUR SUSPENSIONS EXTRACTED AT DIFFERENT H-ION CONCENTRATIONS; AND NITROGEN CONTENTS OF THE EXTRACTS

cc. of N/14 acid or alkali added	pH	Viscosity	Nitrogen extracted			
			1000-cc. extract	500-cc. extract	Total	Total
Alkali		°MacM.	cgm.	cgm.	cgm.	%
3	6.40	43	14.35	2.40	16.75	40.2
0	6.27	66	13.60	2.10	15.70	37.7
Acid						
3	6.07	84	10.75	1.80	12.55	30.2
6	5.88	102	9.70	1.80	11.50	27.6

It has been stated that more electrolytes were extracted at the higher H-ion concentrations. The reason for this was that the optimum concentration for the liberation of phosphates from phytin by the action of the enzyme phytase is on the acid side of neutrality. Anderson (1915) states that more phosphates are liberated in a 0.2% solution of HCl than in other concentrations. No pH values were given. It was, therefore, considered advisable to determine the effect of H-ion concentration on the liberation of electrolytes in flour-water suspensions. Water suspensions containing 18 grams of a first clear flour were accordingly prepared, and these were digested for one hour at the different concentrations as given in Table X. Along with the suspensions digested at different concentrations, check suspensions were digested with pure distilled water. At the end of the digestion period, the same quantity of acid or alkali was added to these suspensions as to the suspensions digested at different concentrations. The resistivities of the suspensions were then determined. It was thought that the suspension digested nearer to the optimum H-ion concentration for the activity of phytase would show the lower resistivity and that the acid or alkali added to the suspensions digested with distilled water at the end of the digestion period would compensate for that added at the beginning to the suspensions digested at different concentrations. Hoffman and Gortner (1924) note, however,

that the reaction between acid or alkali and protein may proceed slowly; hence the resistivities of suspensions in contact with acid or alkali for one hour and for a few minutes may not be strictly comparable. For our purposes it is obvious that this is an objection only when different quantities of alkali are added. The data in Table X show that in every case the resistivity of the suspension digested at the higher H-ion concentration was lower than that of its mate digested at a lower concentration. They also indicate quite conclusively that the H-ion concentration at which the electrolytes were extracted determined the quantity removed.

TABLE IX
VISCOSITIES OF ACIDULATED DURUM FLOUR SUSPENSIONS EXTRACTED AT DIFFERENT H-ION CONCENTRATIONS AND AT TWO DIFFERENT TEMPERATURES; AND NITROGEN CONTENTS OF THE EXTRACTS

Extracted at 25°C.						
cc. of N/14 acid or al- kali added	pH	Viscosity	Nitrogen extracted			
			1000-cc. extract	500-cc. extract	Total	Total
Alkali		°MacM.	cg.	cg.	cg.	%
9.0	7.73	35	16.20	2.75	18.95	48.5
7.5	7.40	30	14.75	2.75	17.50	44.5
6.0	7.11	28	12.70	2.57	15.27	39.1
4.5	6.81	36	10.20	2.52	12.72	32.5
3.0	6.56	46	8.40	2.57	10.97	27.8
1.5	6.30	58	7.30	2.02	9.32	23.8
0.0	6.10	60	7.70	1.95	9.65	24.7
Acid						
1.5	5.85	68	8.00	2.20	10.20	26.1
3.0	5.56	80	9.20	3.40	12.60	32.2
4.5	5.19	102	12.00	4.75	16.75	42.8
6.0	4.95	105	13.50	3.80	17.30	44.3
7.5	4.70	109	15.50	3.70	19.20	49.1
9.0	4.50	83	15.60	3.27	18.87	48.4

Extracted at 40°C.						
cc. of N/14 acid or al- kali added	pH	Viscosity	Nitrogen extracted			
			1000-cc. extract	500-cc. extract	Total	Total
Alkali		°MacM.	cg.	cg.	cg.	%
9.0	7.78	50	15.70	3.07	18.77	48.0
7.5	7.42	56	15.00	2.85	17.85	45.6
6.0	7.18	63	15.40	2.50	17.90	45.8
4.5	6.76	70	10.10	2.90	13.00	33.3
3.0	6.57	88	8.90	2.35	11.25	28.8
1.5	6.27	85	8.50	2.52	11.02	28.2
0	6.05	85	9.00	2.15	11.15	28.5
Acid						
1.5	5.75	104	10.55	2.35	12.90	33.0
3.0	5.44	128	13.20	2.35	15.55	39.8
4.5	5.16	120	17.65	2.67	20.32	52.0
6.0	4.92	113	20.35	2.72	23.07	59.0
7.5	4.67	98	21.55	2.87	24.42	62.5
9.0	4.46	85	22.90	3.07	25.97	66.4

TABLE X
RESISTIVITIES OF FIRST CLEAR FLOUR-WATER SUSPENSIONS DIGESTED AT DIFFERENT
H-ION CONCENTRATIONS

cc. N/14 acid or alkali added	H-ion concentration (as pH) during digestion		Resistivity	
	Alkali or acid added at beginning of digestion period	Alkali or acid added at end of digestion period	Alkali or acid added at beginning of digestion period	Alkali or acid added at end of digestion period
	pH	pH	ohm	ohm
Alkali				
24	....	6.18	574	505
21	9.61	6.18	637	556
18	9.35	6.18	730	606
15	8.72	6.18	805	664
12	8.00	6.18	824	696
9	7.25	6.18	803	727
6	6.93	6.18	814	771
3	6.54	6.18	834	824
1	6.27	6.18	863	859
0	6.18	6.18	...	...
Acid				
1	6.07	6.18	816	830
3	5.81	6.18	759	779
6	5.41	6.18	713	736
9	4.95	6.18	654	660
12	4.48	6.18	582	597
15	4.17	6.18	531	544

It is interesting to note from the data in Table X that the differences between resistivities in each pair were usually greater in the range in which alkali was added than in the range in which acid was added. In the alkaline range the difference was obviously greater than it should be, owing to a too low resistivity of the suspension containing the recently added alkali; while in the acid range, on the other hand, the difference was less than it should be, owing to a too low resistivity of the suspension containing the recently added acid.

The importance of the H-ion concentration in determining the properties of a colloidal system is well known. Its significance in bread making has been discussed by many investigators, among whom are Jessen-Hansen (1911), Cohn and Henderson (1918), Weaver and Goldtrap (1922), and Clark (1923). Bailey and Johnson (1924) and Sharp (1924), moreover, have shown that the H-ion concentration of flour suspensions increased during storage. Since extraction of flours at higher H-ion concentrations resulted in increases in the viscosities of their acidulated suspensions, storage should accomplish the same purpose. The work has not been in progress long enough, however, for us to determine whether or not such suspensions have higher viscosities than similar suspensions of the same flour freshly milled. Sharp had shown that the

H-ion concentration of flours of high moisture content increased more rapidly during storage than that of flours of low moisture content. It was therefore thought that it might be possible to produce in a short time flours capable of yielding suspensions of high concentration if the flours were stored in atmospheres of high relative humidities. Bailey (1920) has shown the relationship which exists between the moisture content of a flour and the relative humidity of the atmosphere. Eighteen-gram portions of flour were accordingly weighed into small evaporating dishes and one set was stored in atmospheres saturated with water vapor while another set was stored at the natural humidity. At the end of 7, 14, 18, and 21 days of exposure to these humidities the viscosities, H-ion concentrations, and resistivities of suspensions of the flour were determined. The suspensions used for the viscosity determination (after acidulation) were extracted with 1 liter and 500 cc. of water at 25° and 40° C. as in the preceding work, the 1000-cc. extracts being used for resistivity determinations. The data obtained at 40° C. are given in Table XI.

TABLE XI
VISCOSITIES OF ACIDULATED FLOUR-WATER SUSPENSIONS PREPARED FROM FLOURS
STORED AT DIFFERENT HUMIDITIES; AND H-ION CONCENTRATIONS AND RESISTIVITIES
OF NON-ACIDULATED FLOUR-WATER SUSPENSIONS

Storage period	Samples stored in dry atmosphere			Samples stored in moist atmosphere		
	H-ion conc. of flour suspension	Viscosity	Resistivity at 25°C.	H-ion conc. of flour suspension	Viscosity	Resistivity
days	pH	°MacM.	ohm	pH	°MacM.	ohm
7	6.10	170	1077	6.10	177	1068
14	6.08	173	1083	5.04	5	1114
18	6.08	175	1075	5.51	2	1081
21	6.05	172	1080	5.88	2	1035

A study of the data in Table XI shows that the flour exposed to the atmosphere saturated with water vapor for 7 days produced an acidulated suspension, the viscosity of which was practically the same as that of the flour stored at the natural humidity. The moisture content of the flour stored in the moist atmosphere was not determined, but the fact that it fell from the evaporating dish in a solid cake indicated that it was high. Moreover, the H-ion concentrations and resistivities of suspensions of the flours stored under the two conditions were practically the same at the end of 7 days. At the end of 14 days, however, the flour stored in the moist atmosphere showed a marked decrease in the viscosity of

its acidulated suspensions, the decrease being from 177 to 5 degrees MacMichael; also the H-ion concentration and the resistivity of suspensions increased. It is likely that molds or bacteria were responsible for these changes. In this regard Treece (1922) states that molds in flours may, under certain conditions of moisture, elaborate enzymes which diffuse from the cell walls of the mold into the substratum (the flour) and there break down such more complex materials as starch and protein into simpler compounds, which may be absorbed by the mold. Within the cell the absorbed substance is further broken down by intra-cellular enzymes and a part of the molecule used by the cell and the waste products are excreted. The waste products usually take the form of organic acids. These phenomena account for the results obtained with flour stored in a moist atmosphere. The protein of this flour was so broken down that water suspensions no longer became viscous on acidulation. The molds, moreover, elaborated organic acids sufficient to change the H-ion concentration from pH 6.10 to pH 5.04. Also the resistivity increased from 1083 ohms for the suspension stored in the dry atmosphere to 1114 ohms for that stored in the moist atmosphere, indicating that molds were apparently utilizing the electrolytes of the flour in their metabolism.

With storage of the flour in moist atmosphere for more than 14 days, the H-ion concentration of their suspensions decreased, indicating that small quantities of ammonia were being formed. The resistivity data substantiated this idea, resistivities decreasing obviously because of increase in electrolytes. The mold was not visually evident at the end of 14 days, but at 18 and 21 days green, blue, and yellow colonies appeared and the cake of flour had to be cut in small bits in order to get it into the flasks. By vigorous shaking it was as completely dispersed as the flour stored in the dry atmosphere.

The rôle of molds in increasing the H-ion concentration of flour suspensions suggests that they may be responsible for the changes in concentration which occur when suspensions are tested at different times during storage of the flour. An investigation along these lines, however, was not attempted.

This series of experiments indicated nothing concerning the effect of storage on the viscosity of acidulated flour-water suspensions. A series of flours has therefore been stored and viscosities of their acidulated suspensions are being determined from time to time.

Viscosity of Unextracted Flour-Water Suspensions

It was stated in the preceding section that at least two factors were responsible for changes in the viscosity of acidulated flour-water suspensions which occurred when they were prepared by previously extracting them with distilled water containing small quantities of added acid or alkali. These factors were: (1) the effect of the H-ion concentration on the activity of phytase; the greater the activity of this enzyme, the greater the quantity of electrolytes removed and, therefore, the higher the viscosity of the final acidulated suspension. (2) The effect of the H-ion concentration to which the proteins were exposed during extraction on the viscosity of the extracted suspensions when conditions were made favorable for maximum viscosity by acidulation to pH 3 with lactic acid. In non-extracted flour-water suspensions containing acid or alkali, the same factors should also affect the viscosity. If flour-water suspensions were digested under such conditions as to increase the activity of phytase, electrolytes should accumulate in the suspension, hence depressing the hydration capacity of the proteins, and, therefore, the resultant viscosity after acidulation should be lower. If such suspensions were digested at concentrations which would render the protein capable of greater hydration finally than when conditions for maximum hydration are favorable, the resultant viscosity should be higher.

With these ideas in mind, experiments were planned using the same patent and first clear flours used for the work recorded in Tables VI and VII. Eighteen-gram portions of the flours were digested at different H-ion concentrations for one hour, the flour being suspended in a total volume of 70 cc. Digestions were carried out at 25° and 40° C. At the end of the digestion period the suspensions were made to a volume of 100 cc. and after acidulation with 1.5 cc. of 75% lactic acid their viscosities were determined. Data obtained are given in Tables XII and XIII.

TABLE XII

VISCOSITIES OF ACIDULATED PATENT FLOUR-WATER SUSPENSIONS DIGESTED FOR ONE HOUR AT DIFFERENT H-ION CONCENTRATIONS AND AT TWO DIFFERENT TEMPERATURES

Digested at 25°C.			Digested at 40°C.		
cc. N/14 alkali or acid added	pH	Viscosity	cc. N/14 alkali or acid added	pH	Viscosity
Alkali		°MacM.	Alkali		°MacM.
24	10.57	6	24	10.51	9
21	10.37	5	21	10.33	9
18	10.14	5	18	10.07	6
15	9.84	13	15	9.82	13
12	9.48	29	12	9.40	24
10	.....	38	..	.....	..
9	8.80	36	9	8.72	38
6	7.50	35	6	7.50	36
3	6.45	38	3	6.50	40
0	6.02	42	0	6.00	43
Acid			Acid		
1	5.69	43	1	5.64	45
2	5.44	44	2	5.41	45
3	5.17	43	3	5.19	41
4	5.00	44	4	4.97	37
5	4.82	43	5	4.80	31
6	4.66	41	6	4.64	32
9	4.17	34	9	4.17	32
12	3.72	31	12	3.77	31
15	3.40	31	15	3.41	32
18	3.11	29	18	3.13	32

TABLE XIII

THE VISCOSITIES OF ACIDULATED FIRST CLEAR FLOUR-WATER SUSPENSIONS DIGESTED FOR ONE HOUR AT DIFFERENT H-ION CONCENTRATIONS AND AT TWO DIFFERENT TEMPERATURES

Digested at 25°C.			Digested at 40°C.		
cc. N/14 alkali or acid added	pH	Viscosity	cc. N/14 alkali or acid added	pH	Viscosity
Alkali		°MacM.	Alkali		°MacM.
24	10.23	6	24	10.18	14
21	9.97	8	21	9.90	10
18	9.68	12	18	9.62	10
15	9.34	16	15	9.24	14
12	8.64	17	12	8.55	17
9	8.01	19	9	7.55	19
6	6.99	21	6	6.94	22
3	6.49	23	3	6.46	24
0	6.18	24	0	6.18	25
Acid			Acid		
1	5.93	25	1	5.90	26
2	5.80	26	2	5.76	26
3	5.65	26	3	5.59	27
4	5.54	26	4	5.49	27
5	5.34	26	5	5.30	26
6	5.20	26	6	5.17	24
9	4.75	22	9	4.71	20
12	4.38	19	12	4.34	20
15	4.07	18	15	3.99	20
18	3.75	17	18	3.72	21

A comparison of the data in these tables with data obtained when the flours were extracted at different H-ion concentrations

shows certain similarities. The viscosities of acidulated suspensions digested with small quantities of added acid were slightly but significantly higher than those of similar suspensions digested with distilled water. It has been shown that the addition of acid to the digesting suspension liberated more electrolytes, hence the increases in viscosity which occurred took place in spite of the presence of increased quantities of electrolytes which would tend to lower the viscosity. The increase in viscosity which occurred, therefore, more than offset the influence of additional electrolytes. Digesting with added acid obviously rendered the flour proteins susceptible to greater hydration when conditions for maximum hydration were made favorable.

Further study of the data in Tables XII and XIII shows that when larger quantities of acid were added to the digesting flour-water suspension, i.e., sufficient acid to make the H-ion concentration equivalent to approximately pH 5, the viscosity of the suspension decreased. The same phenomenon occurred with extracted suspensions, altho in that case it may have been due to extraction of some of the protein responsible for the viscosity. With non-extracted suspensions, however, the falling off of the viscosity of acidulated suspensions digested at H-ion concentrations equivalent to pH 5 and lower, may be due either to the presence of increasing quantities of electrolytes (on account of the increased activity of phytase at high concentrations) or to deleterious effects of the high acidity on the protein. At this time it cannot be stated which factor is the more important. It is noteworthy, moreover, that the falling off of viscosity for both flours in the two tables began to occur at a lower concentration for flour digested at 40° than for that digested at 25° C. The same observation was made in regard to flours extracted at these two temperatures.

With flour suspensions digested with small quantities of added alkali, the viscosity of their acidulated suspensions decreased, just as for flour suspensions extracted at lower H-ion concentrations. For the patent flour, however, a slight rise in viscosity of the acidulated suspension occurred when the suspension was digested at a H-ion concentration of about pH 9. The same phenomenon occurred in extracted suspensions. Again, the rise in viscosity which results when flour suspensions are extracted or digested at this concentration was probably due to the hydroxyl ion rendering the protein capable of greater hydration when conditions for maximum hydration were favorable.

While all the viscosities recorded in this group of experiments are small, it is believed that they are correct and that the changes in viscosity are significant, being due to differences in conditions superimposed upon the system by added acid or alkali. The results recorded represent the average of duplicate determinations.

In another connection, the pH values of the same flour containing the same quantity of acid or alkali show close agreement, whether the digestions were carried out at 25° or 40° C. For the H-ion concentrations encountered in this work, this observation agrees with the results of Henderson, Cohn, Cathcart, Wachman, and Fenn (1919) for crude glutens; and Hoffman and Gortner (1925) for purified prolamines, indicating that the reactions which take place between protein and acid or base are stoichiometric and not absorption phenomena.

In order to determine the effect of small quantities of electrolytes on the viscosity of non-extracted acidulated flour-water suspensions, different quantities of N/14 NaCl solution were added to suspensions of the same patent and clear flours used for the work recorded in Tables XII and XIII, digestion being carried out at only one temperature, 25° C. The standard salt solution was added at the beginning of the one-hour digestion period, the technic being the same as when acid or alkali was added to the unextracted suspensions. The viscosities of the suspensions containing added salt solution are given in Table XIV, and indicate that even the smallest quantities of the salt solution notably decreased the viscosity of the acidulated suspension. The decrease is progressive, larger quantities of the salt solution correspondingly decreasing the viscosity.

TABLE XIV
VISCOSITIES OF ACIDULATED FLOUR-WATER SUSPENSIONS DIGESTED FOR ONE HOUR AT 25°C*

cc. N/14 NaCl solution added	Viscosity	
	Patent flour °MacM.	First clear flour °MacM.
0	42	24
1	40	23
2	35	22
3	33	21
4	31	21
5	29	20
6	27	19
9	22	16
12	18	14
15	15	11
18	12	10
21	8	9
24	6	8

*Small quantities of sodium chloride were added to the suspensions at the beginning of the digestion period.

A comparison of the viscosities of the acidulated suspensions containing added sodium chloride solution with those containing added acid or alkali, shows that the viscosity decreased much more rapidly when salt was added than when the same quantity of equimolar solutions of acid or alkali was added. This indicates that the digestion of flour-water suspensions with small quantities of acid or alkali renders them capable of greater hydration than digestion with a neutral salt as the added electrolyte.

Digestion with acid or alkali rendered the flour proteins susceptible to greater hydration (under conditions for maximum hydration), owing to the effect of hydrogen or hydroxyl ions, than resulted from digestion at or near their iso-electric point.

Iso-Electric Range of Flour Proteins

While it was not the original purpose of this work to determine the iso-electric range of the flour proteins, with the data available from some of the preceding tables it is possible to make certain interesting observations. A protein is at its iso-electric point when it ionizes so as to give the same number of hydrogen ions as hydroxyl ions. At this point a protein suspension offers maximum resistance to the passage of an electric current. Also, as pointed out by Tague (1925b), other properties of the protein are at a maximum or minimum at the iso-electric point. Thus, protein suspensions exhibit their minimum viscosity, minimum hydration, minimum solubility, and maximum precipitability at this point.

As the quantities of protein in suspension have been determined under comparable conditions at a whole series of H-ion concentrations, a study of these data should indicate what might be the iso-electric range of the flour proteins. Tague (1925a) found the iso-electric point of gliadin to be at pH 6.50 and of glutenin to be at pH 7.0. He suggested, however, that these values may not have been correct, as he used purified proteins which may have been denatured in their preparation. In a later paper (1925b) he determined the iso-electric point of the mixture of proteins as they occurred in flour suspensions. In this instance the iso-electric point of the protein of a patent flour was at pH 5.86.

From the work of Jessen-Hansen (1911) it was concluded that the iso-electric point of the flour proteins was at approximately pH 5. The work of Tague as well as the earlier work of Bailey and Le Vesconte (1924) indicated that the iso-electric point was at a pH somewhat higher than this. Bailey and Le Vesconte found

that dough exhibited its maximum extensibility when its suspensions had H-ion concentrations equivalent to pH values between pH 6 and pH 7. Extensibility is no doubt correlated with physical properties of the dough at the iso-electric point.

As our own work appeared to throw further light on the iso-electric range of flour proteins in suspensions, the significant data from several tables were assembled in Table XV. It might be well to state again how the data were obtained. Fifteen minutes before decantation of the supernatant liquid, the flasks containing the flour suspensions were placed at such an angle that most of the material settled at one side of the flask. The decantations were made very carefully, about 970 to 980 cc. of the liquid being decanted. Aliquot portions of the decantate were taken for nitrogen determinations. Using similar technic, aliquots were obtained from the 500-cc. decantates. The sums of the nitrogen in these two decantates, in terms of the percentage of the total nitrogen of the flour, are given in Table XV. The absolute quantity of nitrogen decanted may be obtained by reference to the proper table.

The data in Table XV indicate that with patent, first clear, and durum flours, the least protein was present when the extracts had H-ion concentrations equivalent to pH values between 6.2 and 6.5; while with the second clear flour, the least protein was present in extracts having concentrations equivalent to pH values between 5.50 and 6.00. If it is assumed that proteins exhibit their minimum dispersion or maximum precipitability at their iso-electric points, then the pH values given represent the iso-electric points of the proteins of the respective flours. When suspended in distilled water the proteins of patent, first clear, and durum flours were on the acid side of the iso-electric point, while those of a second clear flour were on the alkaline side of the iso-electric point. Thus for the patent flour (data in Table II at 25° C.) 3 cc. of N/14 alkali was required to bring the proteins to the point of maximum precipitability, while for the second clear (data in Table V at 25° C.) 9 cc. of N/14 acid was required. This seemed peculiar, hence similar determinations were carried out on another second clear flour. The results given in Table VIII are in agreement with those in Table V, viz., that the proteins of second clear flours when suspended in distilled water are on the alkaline side of their point of maximum precipitability.

TABLE XV
PROTEIN EXTRACTED FROM FLOURS OF DIFFERENT GRADE AT DIFFERENT H-ION CONCENTRATIONS

Patent flour in Table II				Patent flour (bleached) in Table III				1st clear flour in Table IV				2nd clear flour in Table V			
Extr. at 25°C.	Extr. at 40°C.	Extr. at 25°C.	Extr. at 40°C.	Extr. at 25°C.	Extr. at 40°C.	Extr. at 25°C.	Extr. at 40°C.	Extr. at 25°C.	Extr. at 40°C.	Extr. at 25°C.	Extr. at 40°C.	Extr. at 25°C.	Extr. at 40°C.	Extr. at 25°C.	Extr. at 40°C.
pH of extract	Total N of extract	pH of extract	Total N of extract	pH of extract	Total N of extract	pH of extract	Total N of extract	pH of extract	Total N of extract	pH of extract	Total N of extract	pH of extract	Total N of extract	pH of extract	Total N of extract
%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
7.64	47.3	7.66	50.1	7.56	53.5	7.52	44.2	8.28	60.2	7.86	58.5	6.85	42.3	.....	.....
7.39	46.3	7.22	43.7	7.30	40.5	7.30	40.5	7.86	58.3	7.54	56.0	6.62	42.1	6.54	43.5
7.15	37.6	7.08	38.4	7.08	35.4	7.05	36.1	7.35	47.6	7.27	48.5	6.37	44.4	6.35	41.6
6.88	36.8	6.90	37.4	6.86	34.5	6.83	33.0	6.93	47.3	7.03	45.8	6.20*	37.4	6.27*	37.8
6.66	36.6	6.76	35.2	6.71	30.4	6.64	31.5	6.69	41.2	6.78	35.3	5.90	31.9	6.10	33.2
6.52	30.7	6.56	31.5	6.51	28.0	6.47	29.5	6.49	35.7	6.57	31.3	5.71	28.0	5.91	31.1
6.35	28.2	6.44	28.2	6.30	28.5	6.36	28.1	6.36	29.2	6.42	27.7	5.49	27.0	5.68	33.6
6.17	29.3	6.20	28.5	6.10	29.2	6.07	33.5	6.27	24.7	6.34	25.8	5.27	28.0	5.41	36.2
5.88	29.5	6.05	30.6	5.80	33.1	5.81	35.7	6.17	25.2	6.24	25.9	5.07	31.3	5.09	41.6
5.75*	31.9	5.80*	34.2	5.53*	38.4	5.51*	42.8	6.00*	25.6	5.90*	28.3	4.90	32.3	4.82	47.4
5.56	36.6	5.53	41.2	5.32	44.3	5.32	49.3	5.70	27.7	5.56	32.7	4.65	32.5	4.38	52.7
5.34	43.9	5.33	50.4	5.09	46.5	5.12	56.1	5.43	32.1	5.26	43.3	4.39	32.4	4.21	51.9
5.15	46.0	5.14	56.0	4.88	50.8	4.97	61.5	5.10	36.6	4.97	50.6	4.12	28.2	3.90	51.3
4.93	50.9	4.99	58.8	4.73	55.5	4.78	64.7	4.85	40.3	4.61	61.0	3.85	28.5	.....	.....
4.77	51.5	4.82	62.5	4.58	60.2	4.60	68.5	4.60	45.2	4.39	67.0	3.60	27.8	.....	.....
4.63	54.3	4.68	64.2	4.34	65.0	4.41	67.0	4.34	49.6	4.12	66.5	3.42	27.5	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	3.97	58.0	.....	.....	3.19	28.3	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	3.73	61.9	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	3.53	59.6	.....	.....	.....	.....	.....	.....

*The pH of the natural flour-water suspension without either acid or alkali.

TABLE XV—Continued

Patent flour in Table VI				1st clear flour in Table VII				Durum flour in Table IX			
Extracted at 25°C.		Extracted at 40°C.		Extracted at 25°C.		Extracted at 40°C.		Extracted at 25°C.		Extracted at 40°C.	
pH of extract	Total N of extract	pH of extract	Total N of extract	pH of extract	Total N of extract	pH of extract	Total N of extract	pH of extract	Total N of extract	pH of extract	Total N of extract
%	%	%	%	%	%	%	%	%	%	%	%
10.31	97.3	....	....	10.29	98.4	10.24	95.4	7.73	48.5	7.78	48.0
9.84	95.5	9.92	88.0	10.11	98.9	10.04	97.7	7.40	44.5	7.42	45.6
9.57	95.0	9.58	88.9	9.86	87.5	9.77	92.5	7.11	39.1	7.18	45.8
9.21	74.2	9.33	80.6	9.35	74.4	9.38	77.0	6.81	32.5	6.76	33.3
8.37	66.0	8.57	64.8	8.30	56.7	8.28	59.2	6.56	27.8	6.57	28.8
7.61	60.5	7.72	54.8	7.25	46.7	7.30	49.8	6.30	23.8	6.27	28.2
6.98	45.2	7.05	44.0	6.71	32.5	6.72	33.8	6.10*	24.7	6.08*	28.5
6.80	37.3	6.85	36.8	6.54	28.4	6.55	28.1	5.85	26.1	5.75	33.0
6.60	32.4	6.66	32.6	6.35	26.4	6.37	28.0	5.56	32.2	5.44	39.8
6.47	29.4	6.54	29.3	6.17*	26.4	6.17*	29.4	5.19	42.8	5.16	52.0
6.34	28.3	6.38	29.1	6.07	28.6	6.03	30.5	4.95	44.3	4.92	59.0
6.19	29.8	6.19	30.4	5.81	28.1	5.83	35.0	4.70	49.1	4.67	62.5
6.05*	32.6	6.02*	35.1	5.61	32.2	5.64	38.8	4.50	48.4	4.46	66.4
5.71	42.2	5.68	46.3	5.15	38.2	5.54	42.1	....	....	....	....
5.39	49.9	5.39	57.8	4.95	49.6	5.42	48.0	....	....	....	....
5.20	55.2	5.17	61.7	4.76	51.2	5.24	50.6	....	....	....	....
5.07	57.6	5.00	64.1	4.48	51.2	5.02	56.5	....	....	....	....
4.82	61.2	4.68	69.6	4.17	51.9	4.90	60.5	....	....	....	....
4.67	67.0	4.53	71.2	....	....	4.80	59.0	....	....	....	....
4.50	72.2	....	....	....	....	....	....	....	....	....	....

*The pH of the natural flour-water suspension without either acid or alkali.

The reasons for the different H-ion concentrations at the iso-electric points (determining by this method) of patent and second clear flours is not known. Michaelis and Rona (1919) noted that different ions operated to shift the iso-electric point of proteins to either the acid or alkaline side depending on the particular ion. They found that the iso-electric point of denatured albumin in sodium acetate—acetic acid buffer solutions to be at pH 5.3; while when the buffer solution was M/60 with respect to potassium iodide, the iso-electric point shifted to pH 5. At higher concentrations of potassium iodide the iso-electric point was shifted still further to the acid side. As regards the mechanism of this shift they state:

“Der Kunstgriff unserer früheren Versuchsanordnung war nun, dass wir nur solche Kationen zuließen, die zu dem Ampholyten eine viel geringere Affinität hatten als die H-Ionen, und nur solche Anionen, die eine viel geringere Affinität hatten als die OH'-Ionen. Wenn die Konzentration der fremden Ionen-arten eine gewisse Grenze nicht überschritt, so kam nur die Wirkung der H- und OH'-Ionen zum Ausdruck.”

Second clear flours, obviously, have a much higher electrolyte content than patent flours, hence this may be the explanation for the different H-ion concentrations at which second clear and patent flour proteins settle most readily from suspensions. Dr. Gortner, at the University of Minnesota, is doing a considerable amount of work on the effect of various ions on proteins, hence this phase of the problem will not be investigated further in this laboratory.

A further study of the data in Table XV indicates that the iso-electric range extended further into the alkaline side when the determinations were made at 40° C. than when they were made at 25° C. In the case of the patent, first clear, and durum flours, this fact is not so evident as it is for the second clear flour. A careful study of the data for the higher grade and durum flours shows, however, that it holds for these flours also. Thus for the second clear flour in Table XV at 25° C. the least protein was dispersed when the pH of the extract was 5.49; while at 40° C. the least protein was removed when the pH was 5.91. Hoffman and Gortner (1924) calculated the iso-electric point of the protein durumini at several temperatures. At 15° C. the iso-electric point was calculated to be at pH 7.39; at 25° C., at pH 7.62; and at 35° C., at pH 8.00. The fact that the iso-electric point was higher at higher temperatures

is in agreement with our data. Hoffman and Gortner suggested that there are two iso-electric points, one in the region in which stoichiometric relationships exist, and another in the region in which absorption phenomena exist. The data which they used to calculate the iso-electric points for durum were obtained in the range of absorption phenomena, hence they consider these iso-electric points as absorption iso-electric points. The mechanism by which the temperature operated to change the iso-electric point is not known. This factor will be subjected to further investigation. It is realized that the methods used for determining iso-electric ranges were quite crude. It is our purpose to repeat some of the work, using more acceptable methods. It is believed, however, that the data obtained justify the observations made.

Discussion

The fact that the extraction or digestion of flours under slightly acid conditions resulted in increasing the viscosity of their acidulated suspensions may be of considerable significance in explaining what takes place during the ageing of flour and during the fermentation of dough with yeast. As the H-ion concentration exhibited by flour-water suspensions becomes greater during storage of the flour, an increase in the viscosity of their extracted suspension should result, owing to extraction of greater quantities of electrolytes at the higher concentration. If storage changes the colloidal conditions of the protein, changes in viscosity should result for this reason also. The work described in this paper has indicated very clearly that extraction or digestion of flours with sufficient acid to increase the H-ion concentration of their suspensions to approximately pH 5 increased their viscosities to a maximum. Certain miscellaneous data have indicated, however, that changes in viscosity which occur during ageing may be due to factors other than the increasing H-ion concentrations of the flour suspensions. In order to investigate this a series of flours has been placed in storage and the work will be reported in due time.

Jessen-Hansen (1911) noted that flours which had been allowed to ferment so that their dough suspensions attained a concentration equivalent to pH 5 were baked into better bread than when the concentration was greater or less than this. The results in this work show that maximum viscosities of acidulated flour-water suspensions were obtained when the suspensions were extracted or digested at concentrations equivalent to approximately

pH 5. When the extractions or digestions were made at concentrations higher or lower than this, the viscosities were lower. It appears, therefore, that some relationship exists between the effects of exposure to this degree of acidity and the colloidal properties of the flour as indicated in one way by optimum baking results and in another way by the maximum viscosity attainable by the acidulated flour-water suspension.

The fact that fermentation with yeast is capable of increasing the viscosity of extracted dough suspensions has already been shown by Sharp and Gortner (1924) altho they did not attempt to explain the mechanism of the changes. They found the viscosity of an extracted suspension of the fresh dough prepared with yeast to exhibit a viscosity (after acidulation) of 538 degrees MacMichael, while immediately before the dough was put in the oven, the H-ion concentration of its suspensions having increased equivalent to approximately pH 5, the viscosity had increased to 1207 degrees MacMichael. A similar dough prepared without yeast showed a comparatively insignificant increase in the viscosity of its extracted suspensions when the viscosities were determined in parallel with those of a dough fermented with yeast. From these data may be seen the relationship between H-ion concentration, viscosity, and bread-making properties. It is hoped that in the future the effects of the electrolytes on viscosity and the influence of the removal of more of them by extraction at higher concentrations may be differentiated from the effects of the exposure of the protein to higher concentrations alone.

There is still another way in which higher H-ion concentrations can operate to influence the bread making properties of flour. This factor, however, may not be of great importance. It is known that in some cases the addition of calcium phosphate to flours improves the quality of the bread baked from them. The data in Table X indicate that at higher H-ion concentrations more electrolytes are elaborated in a flour-water suspension, and as these electrolytes are likely to consist largely of calcium phosphate, the possibility of these phosphates influencing the baking results is obvious. As the flours used for bread making are of relatively low ash content, however, it appears that the increased quantity of salts liberated at higher H-ion concentrations would not be of great significance.

Conclusions

Maximum viscosities of acidulated flour-water suspensions were obtained when extractions or digestions were made at H-ion concentrations equivalent to approximately pH 5.

Maximum viscosities occurred at slightly higher concentrations for suspensions extracted or digested at 25° C. than at 40° C.

Approximately 50% of the nitrogen in the original suspension was decanted from the suspension which exhibited the highest viscosity on acidulation.

Iso-electric ranges of the proteins of patent, first clear, and durum flours, as determined by their range of maximum precipitability, were found to be at H-ion concentrations between pH values 6.2 and 6.5; while for the proteins of a second clear flour the iso-electric range was found to lie between pH values 5.5 and 6.0.

Iso-electric ranges were slightly farther toward the alkaline side when determined at 40° C. than when determined at 25° C.

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REFRACTIVE INDICES OF AQUEOUS AND ALCOHOLIC EXTRACTS OF FLOUR

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This investigation was carried out primarily with a view to determining whether the change in refractive index of a flour extract with concentration was at all indicative of the "strength," or any other important quality, of the flour.

The authors have not found many references to such matter in the literature of flour chemistry; the following, however, may be mentioned: Stockham (1920), Robertson and Greaves (1911), Bailey (1925), Dingwall (1924), and Kent-Jones (1926).

From the point of view of this investigation the statements of Stockham and of Bailey were the most important. As a preliminary, therefore, the experiments in both these references were repeated, but in neither case could the results be confirmed.

Aqueous Extracts

Stockham correlated the refractive index of the aqueous extract with the amount of soluble extract in the flour.

In repeating his experiments, five flours were chosen and the refractive indices of their aqueous extracts determined. The method he gives was adopted, except that the refractive index was taken on an Abbé refractometer at a temperature of 20° C., whereas he used an immersion refractometer at 17.5° C. After the refractive index had been taken, the soluble extract was determined by evaporating 50 cc. of the aqueous extract to dryness in a silica basin on a water-bath, drying for two hours in a water-oven and weighing. Stockham's method of preparing the aqueous extract is as follows:

"25 grams of flour are placed in a tight container with 100 cc. of water and shaken vigorously by a shaking machine for thirty minutes. The liquid portion is filtered and read by the refractometer one hour after the beginning of the test."

The results are given in Table I.

Although there is a considerable difference between the amount of soluble extract in the various flours, it is evident that there is

no significant difference between the refractive indices of the corresponding extracts. It is suggested that 0.0003 units is the smallest significant difference under the conditions of the experiment, as the error in determination is ± 0.0001 .

TABLE I
AMOUNT OF SOLUBLE EXTRACT (DETERMINED BY STOCKHAM'S METHOD) OF VARIOUS
FLOURS AND THE REFRACTIVE INDEX OF THE CORRESPONDING EXTRACTS

Flour	Soluble extract, %	Refractive index(20°C.)
A	5.65	1.3350
B	5.28	1.3350
C	5.09	1.3350
D	4.35	1.3348
E	4.63	1.3350
Distilled water used	....	1.3333

A further series was examined, but in this case the extract was prepared by the following method (Kent-Jones 1927):

"20 grams of flour are put into a graduated flask and water added up to the 200 cc. mark. The flask is stoppered and shaken for five minutes exactly, and then allowed to stand for thirty minutes. The fairly clear solution at the top is then poured through a No. 5 Whatman—the first few ccs. not being very clear, being neglected or re-filtered."

The refractive index of this solution was taken at 20° C. on an Abbé refractometer, and 50 cc. treated as before to determine the soluble extract. In this series, of course, the refractive indices of the aqueous extracts are lower than those in Table I, since here we are dealing with a 10% extract.

The two wheats included in this series were ground on a small coffee mill and sifted by a model plansifter to give a 45% extraction.

Some of the flours given in Table II were those used by Kent-Jones (1926).

The "heated" Manitoba flour in this series was the "normal" flour which had been heated at 160°F. for 1½ hours; the "heated" English flour being the "normal" English which had been heated at 160° F. for one hour. The two straight-run flours were taken from a commercial mill grinding a blend of wheats. The heat treatment in this case was done on the dry wheat before conditioning.

The effect of this heat treatment was to increase materially the strength and improve the baking properties of the flour.

Although there is in Table II a range of soluble extract from 4.23 to 5.27% (in the flours), no significant difference is observed in the refractive index.

TABLE II
AMOUNT OF SOLUBLE EXTRACT (DETERMINED BY METHOD OF KENT-JONES) OF VARIOUS
FLOURS AND THE REFRACTIVE INDEX OF THE CORRESPONDING EXTRACTS

Flour	Soluble extract, %	Refractive index (20°C.)
Manitoba normal	5.00	1.3340
Manitoba heated	4.97	1.3340
English normal	4.88	1.3340
English heated	4.23	1.3340
Straight-run flour normal	5.27	1.3340
Straight-run flour heated	5.14	1.3338
Wheat blend for straight-run flour	5.84	1.3340
Karachi wheat	5.74	1.3340
Bran No. 1	12.22	1.3351
Bran No. 2	12.11	1.3359

The results in Tables I and II show that no correlation could be found between the soluble extract of a flour and the refractive index of its aqueous extract.

Stockham also stated:

"It will be found on comparing results obtained by the refractometer with the quantity of gas generated . . . that there is a marked relationship between them."

This statement has been investigated by Kent-Jones (1926), who took a series of flours of greatly different gassing powers and estimated the refractive indices of their extracts (prepared according to Stockham) at 20° C. (Abbé refractometer).

The gassing powers of the flours were estimated by the percentage of maltose produced after incubation at 27° C. for one hour. The method is an adaptation of that advocated by Rumsey (1922). Kent-Jones checked the validity of the maltose percentages by actual gas-production tests.

His results are given in Table III, from which it will be seen that flour "M," which has a high maltose percentage and which gasses well, has the same refractive index as "C," which gasses very poorly. In fact, although the series consists of flours of greatly varying gassing power, the refractive indices are practically constant.

Bailey (1925) observed that the lower grade or clear flours yielded an extract with somewhat higher refractive index than the high grade or patent flours, altho he concluded that it was doubtful if the difference is great enough to make possible the classification of flours on the basis of this property. When a series

of flours with gradually increasing ash content was studied, the refractive index of their extracts did not likewise increase in a regular manner, altho as between the flours with the highest and the lowest content of ash, there was an appreciable difference in the refractive index of their extracts.

TABLE III
GASSING POWER OF VARIOUS FLOURS AND THE REFRACTIVE INDEX OF THEIR AQUEOUS
EXTRACTS (PREPARED BY STOCKHAM'S METHOD)

Flour	Gassing power, %	Refractive index (20°C.)
A	1.68	1.3351
B	1.73	1.3352
C	<1.00	1.3350
D	<1.00	1.3349
E	1.16	1.3351
F	<1.00	1.3350
G	1.33	1.3351
H	<1.00	1.3348
K	1.65	1.3350
L	1.40	1.3350
M	2.10	1.3350

Further, he stated that if the aqueous extract of the lower grade flours were heated in boiling water for 30 minutes, the refractive index falls to that of the patent flour. Hence he suggested that it is probable that the difference between the refractive indices of patent and low-grade flours is due to the soluble proteins. The coagulation of these by heat and their removal, therefore, brought the flour to the same refractive index.

To test these points, duplicate ash determinations were carried out on a series of flours. Twenty-five grams of the flour were then extracted with 100 cc. of water and the refractive index of the extract was taken at 20° C. The extract was then heated in a bath of boiling water for 30 minutes and the refractive index again taken at 20° C.

A nitrogen estimation, also, was carried out on the extract both before and after heating. The results obtained are given in Table IV.

Excluding the "sharps, or middlings," in Table IV it is seen that, although the ash content of the flours varies from 0.35 to 1.06% (Bailey's varied from 0.43 to 0.90%), yet within the limits of experimental error the refractive indices are the same.

The nitrogen figures show that the matter precipitated on heating in boiling water is nitrogenous, but the refractive index after heating is the same as that before, hence the protein—or to be more exact the nitrogenous matter coagulated by heat—does not appear to influence the refractive index.

It was found that continued heating in boiling water did not result in any further precipitation or alteration of the refractive index.

TABLE IV
REFRACTIVE INDICES AND NITROGEN CONTENT OF AQUEOUS EXTRACTS BEFORE AND AFTER HEATING IN BOILING WATER FOR 30 MINUTES, OF FLOURS OF VARYING ASH CONTENT

Flour	Ash, %	Refractive index		gm. nitrogen per 100 cc. extract	
		Original extract	Extract after heating	Original extract	Extract after heating
Patent	0.35	1.3350	1.3350	0.058	0.044
No. 2 Manitoba	0.44	1.3350	1.3350	0.063	0.056
Barusso Plate	0.46	1.3349	1.3349	0.058	0.040
Commercial flour (straight-run)	0.47	1.3350	1.3350	0.060	0.044
Bottom 50% of a mill	0.55	1.3350	1.3350	0.049	0.040
Low-grade flour (lower than used commercially)	0.60	1.3350	1.3349	0.054	0.037
Flour scraped off bran (IVth break)	1.06	1.3351	1.3350	0.070	0.054
Sharps, or middlings	3.94	1.3385	1.3382	0.188	0.090

70% Ethyl Alcohol Extracts

Previously to carrying out the experiments with alcoholic extracts, the concentration/refractive index curve at 20° C. for gliadin in 70% ethyl alcohol was determined.

The gliadin was prepared by a method which was essentially that described by Osborne (1909).

The final sample of gliadin was not absolutely dry, although it was free from other protein; the actual gliadin content was determined by duplicate nitrogen determinations. The gliadin present in the solutions of various concentrations was determined by nitrogen determinations and also checked from the amount weighed out and the known gliadin content of the sample; the two results agreed very closely.

The refractive indices were taken on an Abbé refractometer at 20° C.

The results are given in Table V and also produced in the graph.

TABLE V
REFRACTIVE INDICES OF SOLUTIONS OF GLIADIN IN 70% ETHYL ALCOHOL

Grams gliadin per 100 cc. of solution	Refractive index
0.00	1.3634
0.68	1.3646
0.90	1.3650
1.12	1.3654
1.34	1.3658

The equation to the curve will be of the form

$$\mu_s = 1.3634 + aC$$

where

μ_s = the refractive index of the gliadin solution at 20° C.

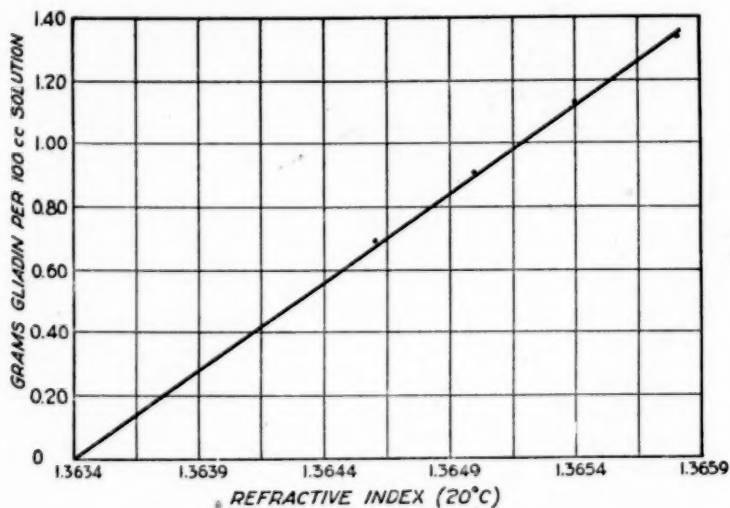
C = concentration in grams per 100 cc. of the solution.

a = a constant.

Substituting from the above data we have

$$\mu_s = 1.3634 + 0.0018 C.$$

Robertson and Greaves (1911) working at 25° C. obtained the value 0.00152 ± 0.00006 for "a."



For the experiments with alcoholic flour extracts, four flours, all straight grades, which varied in strength, were chosen; they were English, Barusso Plate, Manitoba, and a commercial baking flour made from a blend.

Each flour was taken separately and alcoholic extracts of different concentrations were prepared from it. After the refractive index of the alcoholic extracts had been taken, a nitrogen determination was carried out on them. The extracts were prepared as follows: x grams of flour (where $x = 3.75, 6.25,$ and 8.75 , respectively) were weighed into a large boiling tube and 25 cc. of 70% ethyl alcohol was added. The tube was stoppered and shaken in a mechanical shaker for 15 minutes. The liquid was filtered through a No. 5 Whatman paper.

Table VI gives the refractive index of the various extracts and Table VII gives the corresponding nitrogen contents expressed as grams of gliadin per 100 cc. of extract.

Table VI shows that for corresponding concentration of extract, there is a difference in refractive index for the various flours, but even if this difference could be correlated with the "strength" it is too small to be of any use. Thus, between the refractive indices of extracts of corresponding concentration of English and Manitoba flour—typically "weak" and "strong" flours respectively—there is a difference of only 0.0007-0.0008 units.

TABLE VI
REFRACTIVE INDICES OF 70% ETHYL ALCOHOL EXTRACTS OF DIFFERENT CONCENTRATIONS OF FLOURS

Concentrations of extract gm. of flour per 100 cc. alcohol	Flour used			
	English	Barusso Plate	Commercial	Manitoba
15	1.3650	1.3652	1.3654	1.3657
25	1.3660	1.3662	1.3664	1.3667
30	1.3670	1.3672	1.3673	1.3678

Table VII indicates that this difference is due mainly to the concentration of the gliadin in the extract; the flours would fall in the same order whether grouped according to the refractive index of an extract or to the gliadin content of the same extract.

TABLE VII
NITROGEN CONTENTS (AS GM. GLIADIN PER 100 CC. EXTRACT) OF THE EXTRACTS GIVEN IN TABLE VI

Concentrations of extract gm. of flour per 100 cc. alcohol	Flour used			
	English	Barusso Plate	Commercial	Manitoba
15	0.77	0.82	0.84	0.86
25	1.27	1.36	1.37	1.46
30	1.78	1.91	1.91	2.04

That the refractive index is not entirely due to the gliadin, however, is shown by Table VIII. Here the calculated and observed values for the refractive indices of the various extracts are given. The calculated values are obtained by substituting the gliadin content of the extract in the equation

$$\mu_s = 1.3634 + 0.0018 C. \text{ (assuming that all the nitrogen is due to gliadin).}$$

Table IX shows the difference between the calculated and observed values of the refractive indices of the extracts of different concentrations. It will be seen that within the limits of experimental error, this difference is constant for each flour but differs with the flours.

TABLE VIII
CALCULATED AND OBSERVED VALUES OF THE REFRACTIVE INDEX OF VARIOUS EXTRACTS
OF DIFFERENT FLOURS

Flour		Concentration of extract gm. of flour per 100 cc. alcohol		
		15	25	35
English	Calculated	1.3648	1.3656	1.3666
	Observed	1.3650	1.3660	1.3670
Barusso Plate	Calculated	1.3649	1.3658	1.3668
	Observed	1.3652	1.3662	1.3672
Commercial flour (straight-run)	Calculated	1.3649	1.3659	1.3669
	Observed	1.3654	1.3664	1.3673
Manitoba	Calculated	1.3649	1.3660	1.3671
	Observed	1.3657	1.3667	1.3678

This difference is undoubtedly accounted for by substances, other than gliadin, extracted by the alcohol. That a considerable amount of other matter is extracted is natural. For instance, a flour was taken and an alcoholic extract made according to the A. A. C. C. tentative method for the estimation of gliadin. The gliadin in this extract was determined according to the method and 50 cc. of the extract was evaporated to dryness, dried, and weighed. The gliadin was 5.16% while the total solids amounted to 7.96%.

TABLE IX
DIFFERENCE BETWEEN OBSERVED AND CALCULATED VALUES OF THE REFRACTIVE INDEX
OF AN EXTRACT FOR FLOURS OF TABLE VIII

Concentration gm. flour per 100 cc. alcohol	Observed value minus calculated value			
	English	Barusso Plate	Commercial (straight-run)	Manitoba
15	0.0002	0.0003	0.0005	0.0008
25	0.0004	0.0004	0.0005	0.0007
35	0.0004	0.0004	0.0005	0.0007

It was thought that perhaps the refractive index of an alcoholic extract might be due mainly to the gliadin extracted but also partly to the gassing power of the flour (as suggested by Stockham in the case of aqueous extracts). This point was tested by taking several flours with approximately the same gluten content but different gassing powers. The flours of each series were milled from blended wheats and, apart from the gassing powers, were of a kindred nature, so that as the gluten contents are the same, the protein distribution will also, within small limits, be the same for each.

Extracts of 15 per cent, 25 per cent, and 35 per cent in 70 per cent alcohol were prepared from each and the refractive index taken at 20° C. The results are given in Table X.

This table shows that the gassing power does not affect the refractive index of an alcoholic solution. Thus in series 2, flours

A and B have widely different gassing powers; A gasses almost too well, while B is essentially a very bad gasser. Yet the refractive index is approximately the same.

TABLE X
REFRACTIVE INDICES OF 70% ALCOHOLIC EXTRACTS OF FLOURS HAVING APPROXIMATELY
THE SAME PROTEIN CONTENT BUT DIFFERENT GASSING POWER

Flours	Nitrogen (%)	Protein content (Nx5.7)	Concentration of extract, %			Gassing power, % maltose after 1 hour incubation at 27°C.
			15	25	35	
Series 1						
A	1.65	9.41	1.3649	1.3659	1.3668	1.87
B	1.60	9.12	1.3650	1.3660	1.3669	2.58
C	1.68	9.58	1.3649	1.3658	1.3668	3.39
Series 2						
A	1.95	11.12	1.3649	1.3660	1.3670	3.40
B	1.87	10.66	1.3649	1.3660	1.3668	1.12

The effect of the protein content, and hence the gliadin, of a flour upon the refractive index of the extracts is further illustrated by the two flours in Table XI. These two flours had equal gassing power but widely different protein contents.

TABLE XI
REFRACTIVE INDICES OF 70% ALCOHOL EXTRACTS OF FLOUR HAVING APPROXIMATELY
THE SAME GASSING POWER BUT DIFFERENT PROTEIN CONTENTS

Flour	Nitrogen %	Protein content (Nx5.7)	Concentration of extract, %			Gassing power, % maltose after 1 hour incubation at 27°C.
			15	25	35	
A	2.61	14.88	1.3653	1.3670	1.3683	2.18
B	1.64	9.35	1.3649	1.3660	1.3668	2.10

Methyl Alcohol Extracts

Blish and Sandstedt (1925), in a paper on the preparation and estimation of glutenin, give a method by which all the proteins of a flour can be obtained in a methyl alcohol solution and then the glutenin precipitated, leaving the other proteins in solution.

It was thought that perhaps this methyl alcohol solution of the proteins, when examined as to its refractive index, might furnish some interesting results.

The procedure was as follows:

x grams of flour (where x=2, 4, 6, or 8) was weighed into a dry 100 cc. flask and thoroughly mixed with 25 cc. of water; 2.5 cc. N/1 NaOH was then added, during which process the flask was vigorously rotated. The flask was then allowed to stand for one hour, being shaken every 10 minutes. Methyl alcohol was then added in portions of about 30 cc. up to the 100 cc. mark, with shaking after each addition. Then y cc. of methyl alcohol was add-

ed in excess (where $y = 1.25, 2.5, 3.75$, or 5 according as to whether $x = 2, 4, 6$, or 8). After standing for two hours, a portion of the supernatant liquid was centrifuged and then filtered through a No. 5 Whatman paper. The refractive index of the filtrate was taken at 20°C . Then 25 cc. of the filtrate had a few drops of brom-thymol blue solution added to it and then $N/5\text{ HCl}$ run in until the colour changed to olive green. The solution was then kept at 37°C . for one hour, the supernatant liquid centrifuged, filtered through a No. 5 Whatman paper, and the refractive index taken.

Three flours, an English, a No. 2 Manitoba, and a commercial flour (straight-run) were subjected to the above procedure and the results obtained are given in Table XII.

The refractive index of the compound solvent before and after the addition of brom-thymol blue and $N/5\text{ HCl}$ was taken and was found to be 1.3450 in each case.

The results are not very helpful. With the solutions in which 2 grams of flour was used the refractive index is, within the limits of experimental error, the same as that of the "blank."

Using 4 grams of flour, the Manitoba and straight-run give a reading higher than the blank, while the English (which contained 2% less total protein than the straight run and nearly 4% less than the Manitoba) gave a figure approximately the same as the blank.

With all the flours the refractive index of the protein solution after the precipitation of the glutenin is approximately the same as before.

TABLE XII
REFRACTIVE INDICES OF EXTRACTS OF FLOURS CONTAINING RESPECTIVELY THE TOTAL PROTEINS AND THE TOTAL PROTEINS LESS GLUTENIN

Flour	Gm. of flour used	Refractive index (20°C.) of solution containing	
		Total proteins	Total proteins less glutenin
English	2	1.3450	1.3450
	4	1.3452	1.3451
	6	1.3458	1.3456
	8	1.3461	1.3460
No. 2 Manitoba	2	1.3451	1.3450
	4	1.3459	1.3459
	6	1.3461	1.3459
	8	1.3461	1.3459
Commercial (straight-run)	2	1.3451	1.3451
	4	1.3459	1.3457
	6	1.3460	1.3459
	8	1.3461	1.3461

Summary

Stockham's statement that the refractive index of an aqueous flour extract is correlated with its soluble extract could not be confirmed.

No confirmation was obtained of Bailey's observations upon the effect of the protein coagulated by heat on the refractive index of an aqueous flour extract.

The concentration/refractive index curve for gliadin in 70% ethyl alcohol at 20° C. was determined. The equation to the curve was found to be

$$\mu_s = 1.3634 + 0.0018 C.$$

where

μ_s = refractive index at 20° C. of gliadin solution
and

C = concentration of gliadin solution expressed as gm. gliadin per 100 cc. of solution.

The change in refractive index of a 70% ethyl alcohol extract of flour with concentration is due chiefly to the gliadin. It is also affected slightly by other substances extracted by the alcohol. This slight effect due to substances other than gliadin is not connected with the gassing power.

The refractive index of the alkaline methyl alcohol solution of the total proteins apparently indicates nothing useful as to the baking qualities of the flour.

The refractive index of a methyl alcohol solution of the total proteins of flour is affected but slightly by the glutenin.

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WHEAT AND FLOUR STUDIES XIII

THE RELATION BETWEEN THE FUSIBILITY OF FLOUR ASH AND ITS MINERAL CONSTITUENTS¹

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Introduction

The importance of the ash determination has been recognized for a long time by cereal chemists and those interested in the properties of cereal products. This naturally led to considerable work being done on methods of conducting the determination. In this work it has been emphasized that white fluffy ashes are more desirable than fused or partially fused ashes, as the latter give irregular results. According to the official methods of the A. O. A. C., the ash determination is conducted by incinerating the proper quantity of material in a furnace at approximately 550° C. until no further loss in weight occurs. It has been our experience and that of other investigators, however, that under these conditions a white and fluffy ash does not always result. Under apparently identical conditions of incineration, some flours always yield white fluffy ashes, others yield partially fused ashes, while still others yield completely fused ashes. It was thought that these varying ash characteristics might be related to the constituents of the ash and the proportion of each in the ash. In order to determine this, the investigations reported in this paper were conducted.

Historical

Many investigators have determined the constituents of the ash from flour and other cereal products but only a few have recorded any observations concerning the relation between ash constituents and ash characteristics. Dempwolf (1869), Teller (1896), and Grossfeld (1920) have shown that the percentage of magne-

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sium oxide in flour ash increases as the grade of flour decreases while the percentage of calcium oxide decreases as the grade of flour decreases. The flour grade, therefore, appears to determine the relative quantities of magnesium oxide and calcium oxide in the ash, and as it has been noted that flours of all grades may give either fluffy or partially fused or completely fused ashes, differences in these constituents would not be expected to account for differences in fusibility of the ash.

Sullivan and Near (1927) present data which bear more directly on the relation between ash constituents and ash characteristics. They found that flours having the highest phosphorus pentoxide content were the most difficult to ash. They state further that the phosphorus in flour ash exists mostly as pyrophosphate together with some metaphosphate. When high percentages of phosphorus are present, the percentages of metaphosphate in the ash are higher and the fusion temperatures are lower. They cite the instance of a patent flour the ash of which had a phosphorus pentoxide content of 55.20 per cent and possessed metaphosphate and pyrophosphate in the ratio of one to four respectively. The ash of the wheat from which this flour was milled contained 50.67 per cent of phosphorus pentoxide and consisted almost entirely of the pyrophosphate.

Experimental

During the last two years a large number of ash determinations on flour have been made in this laboratory. The usual procedure has been to use 5 grams of the flour and after charring the material over a free flame to incinerate it for 16 hours in an electric muffle maintained at 585° C. The ashes thus obtained were classified into three groups and saved until quantities large enough for chemical determinations were available. The three types of ash were classified as white and fluffy, partially fused, and completely fused. The white and fluffy ashes could readily be brushed from the platinum dishes in which the determinations were made. The partially fused ash could be broken from the dish in small irregular shaped pieces but as it could not be completely removed in this way, it was dissolved out with nitric acid and stored in solution. The completely fused ash could be removed from the dish only by dissolving with nitric acid. When about 2 grams of each type of ash had been obtained, the mineral constituents of each were determined. Before using for the analytical work, the white fluffy ash was ignited to constant weight. The solutions containing

the other two types of ash were carefully evaporated to dryness and then heated at 585° C. until constant weight was attained.

As the mineral constituents of flour ash are largely potassium, calcium, magnesium, and phosphorus, the greatest significance was attached to the proportions of these elements in relation to the fusibility of the ash. The iron content and, in one case, the silicon content of these ashes were also determined. McHargue (1925) and Sullivan and Near (1927) have found other minerals in wheat and flour ash but in such small quantities that it was thought that the small difference in the content of these elements would not influence markedly the characteristics of the ash.

Silicon, phosphorus, calcium, and magnesium were determined on the same weighed sample. Phosphorus determinations were made by the gravimetric pyrophosphate method, the calcium and magnesium being determined on the filtrate from the phosphorus determination. Calcium was determined by the volumetric permanganate method and magnesium by the method of Schmitz as given in Treadwell and Hall (1919). Potassium was determined on a separate portion of the ash by the perchloric acid method. Iron was also determined on a separate portion of the ash by the Lachs and Freidenthal method (1911).

Results are given in Table I, a study of which shows no significant variation in the percentages of calcium oxide or magnesium oxide which might explain the differences in physical characteristics of the three types of ash. The completely fused ash was lowest in calcium oxide content, the partially fused ash highest, and the fluffy ash intermediate. The completely fused ash was highest in the percentage of magnesium oxide, the partially fused ash lowest, and the fluffy ash intermediate. Considerable differences appear, however, in the phosphorus pentoxide and potassium oxide contents of the three types of ash. The white fluffy ash is lowest in phosphorus pentoxide content, the partially fused ash intermediate, and the completely fused ash highest. Thus the phosphorus pentoxide contents of the three ashes were 47.95, 52.68, and 54.50 per cent respectively. The potassium oxide content of the three types of ash, on the other hand, decreased as the susceptibility of the ashes to fusion increased. Thus the white fluffy ash had 32.89 per cent of potassium oxide, the partially fused ash 28.93 per cent, and the completely fused ash 25.73 per cent. It appears, therefore, that white fluffy ashes are characterized by relatively high percentages of potassium oxide and relatively low percentages of phos-

phorus pentoxide; and that susceptibility to fusion increases as the percentage of potassium oxide in the ash decreases and as the percentage of phosphorus pentoxide in the ash increases.

TABLE I
MINERAL CONSTITUENTS OF THREE TYPES OF ASH OBTAINED ON ROUTINE ASH DETERMINATIONS OF SEVERAL HUNDRED SAMPLES OF FLOUR

Mineral constituents	Ash No. 1 Fluffy	Ash No. 2 Partially fused	Ash No. 3 Completely fused
	%	%	%
SiO ₂	.....	0.632	.....
P ₂ O ₅	47.95	52.68	54.50
CaO	6.98	7.68	5.81
MgO	11.76	10.17	12.45
K ₂ O	32.89	28.93	25.73
Fe ₂ O ₃	0.437	0.437	0.445

TABLE II
MINERAL CONSTITUENTS OF THE ASH FROM EACH OF THREE FLOURS HAVING APPROXIMATELY THE SAME ASH CONTENT BUT DIFFERENT ASH CHARACTERISTICS

Mineral constituents	Ash No. 4 Fluffy	Ash No. 5 Partially fused	Ash No. 6 Completely fused
	%	%	%
SiO ₂	0.708	0.701	0.677
P ₂ O ₅	48.51	53.56	54.56
CaO	7.96	8.58	6.76
MgO	10.90	10.72	12.54
K ₂ O	32.02	27.02	25.12
Fe ₂ O ₃	0.512	0.538	0.523

As the ashes used for the work described were derived from a large number of flour samples of different grade, and as Dempwolf (1869), Teller (1896), and Grossfeld (1920) have shown that the proportions of certain of the ash constituents vary with the flour grade, the work was repeated, using three flours of approximately the same ash content but of different ash characteristics. Sufficient flour was ashed that about 2 grams of each ash was obtained. The flours were ashed in a large platinum dish at a temperature of 585° C. Ashes 4, 5, and 6 (Table III) were thus obtained; ash 4 being white and fluffy; ash 5, partially fused; and ash 6, completely fused. A study of the data in Table II indicates that the respective ash constituents were present in the three types of ash in precisely the same order as in the three types of ash given in Table I, even as regards the quantities of calcium oxide and magnesium oxide.

In addition to determining the mineral constituents of ashes from flours 4, 5, and 6, the ash content of each flour was determined at several different temperatures and the characteristics of the ash were noted. Five-gram samples were used for this purpose and the determinations made in duplicate. The period of incineration was 16 hours. The data thus obtained are given in

Table III. A study of these data shows that ash 4 was not completely fused until the determination was made at 685° C., while ash 5 was completely fused at 585° C., and ash 6 completely fused at 555° C. At temperatures below these, fluffy ashes were obtained in all cases, altho some were gray or black.

TABLE III
ASH CONTENT AND CHARACTER OF ASH OF EACH OF THREE FLOURS DETERMINED AT DIFFERENT TEMPERATURES

Temperature °C.	Ash content			Character of ash		
	Flour 4	Flour 5	Flour 6	Flour 4	Flour 5	Flour 6
	%	%	%			
485	0.478	0.490	0.487	White and fluffy	Gray and fluffy	Black and fluffy
505	0.484	0.490	0.482	White and fluffy	White and fluffy	Gray and fluffy
555	0.480	0.490	0.485	White and fluffy	Partially fused	Fused
585	0.480	0.492	0.488	White and fluffy	Fused	Fused
615	0.482	0.486	0.485	White and fluffy	Fused	Fused
685	0.485	0.490	0.487	Partially fused	Fused	Fused
725	0.478	0.491	0.470	Fused	Fused	Fused
750	0.453	0.462	0.458	Fused	Fused	Fused

It is interesting to note that at all temperatures of incineration lower than 750° C. the ash content of the flours is the same regardless of the type of the ash. When ashed at 485° C. flour 6 yielded a black fluffy ash and its ash content was apparently no higher than that obtained when the temperatures of incineration were high enough that gray and fluffy or completely fused ashes resulted. Similar observations may be made in regard to the ashes from flours 4 and 5. The ash from flour 6 is, however, the extreme case.

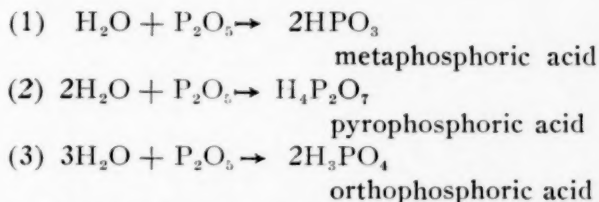
Discussion

Sullivan and Near (1927) state that in the commercial testing of flours for their ash content erroneous results are often reported for some flours because all flours are treated alike. They further state that the rigid standardization of the ash method as to exact temperature and time is unscientific and inaccurate, as conditions of time and temperature which will produce a clean ash fit to weigh for one flour, often cause a fused or insufficiently burned ash with another sample whose ash has a different composition. While it is recognized that the same conditions of time and temperature may not always produce ash of the same characteristics, yet on the basis of the data given in Table III it does not appear that standardization of conditions of incineration are necessarily responsible for inaccurate results. Thus when the time of incineration was 16 hours and the temperature varied between 485° and 685° C., practically check results were obtained for each flour regardless of the

characteristics of the ash. Even tho some of the ashes were gray or even black, the quantity of carbon responsible for the color was apparently so small that the dark ashes showed no greater weight than whiter ashes obtained at higher temperatures.

There are many statements in the literature concerning the reliability of results when the ash is fused. Coleman and Christie (1925) obtained slightly higher values when the ash was determined at 685° or 785° C. (at which temperatures fusion occurred) than at 585° C. where fusion did not occur. They state that they obtained the most uniform results when the sample was heated for 16 hours at 585° C., higher or lower temperatures yielding irregular results. Our data in Table III show practically replicate results for all temperatures up to 725° C., above which temperature there appears to be a very definite loss of ash.

Other investigators state that when fused ashes are obtained the results are likely to be low. Goldtrap (1917) and Weaver (1920) explain the loss in weight at high temperatures of incineration as being due to the reduction of phosphates to metaphosphates at the fusion temperature. They state further that nitric acid may be used to oxidize the metaphosphate to the orthophosphate, thereby restoring the original weight. A study of the reactions involved, however, indicates that if these changes in weight occur at all they are not due to reduction and oxidation but rather to dehydration and hydration. This may be seen from the following reactions:



Thus the difference between orthophosphoric acid and metaphosphoric acid is one molecule of water, or the difference between potassium orthophosphate and potassium metaphosphate is a molecule of potassium oxide. Potassium metaphosphate and potassium orthophosphate both have hydrated forms but at the temperatures used in making the ash determination the water of hydration is lost and the phosphates in the ash are not in the hydrated form.

Sullivan and Near (1927) state that the phosphorus in flour ash exists for the most part in the pyrophosphate form, with small proportions of the metaphosphate, and that when the phosphorus

in the metaphosphate form is high, the ash is more susceptible to fusion at temperatures at which ash determinations are usually made. In our work determinations of the various phosphates were not made, but by calculations of the oxygen in base to oxygen in acid ratio (as is done in metallurgy), a knowledge may be gained of the relative proportions of each phosphate present in the ash. By a study of equations 1, 2, and 3 it may be noted that these ratios for the metaphosphate, pyrophosphate, and orthophosphate are 1:5.00, 1:2.50, and 1:1.66 respectively. When the ratios are calculated for the combinations of bases and acids in the ashes in Table I, the ratio for the fluffy ash is 1:2.18; for the partially fused ash, 1:2.66; and for the completely fused ash, 1:2.76. A comparison of these ratios with those of the pure metaphosphate, pyrophosphate, and orthophosphate indicates that the fluffy ash contained pyrophosphate and orthophosphate with the pyrophosphate predominating; and the partially fused and completely fused ash contained pyrophosphate and metaphosphate, again with the pyrophosphate predominating but with more of the metaphosphate in the completely fused ash than in the partially fused ash.

Similar calculations were made for the ashes in Table II. The white fluffy ash gave a ratio of oxygen in base to oxygen in acid of 1:2.27; the partially fused ash, a ratio of 1:2.66; and the completely fused ash, a ratio of 1:2.75. Comparison of these values with those of the pure phosphates leads one to draw the same conclusions as were drawn from similar calculations for the data in Table I. It appears, therefore, that most of the phosphorus in flour ash is in the pyrophosphate form. In ashes which do not fuse readily, some of the phosphorus is in the orthophosphate form while in those that fuse more readily some of it is in the metaphosphate form. Obviously the more phosphorus in the orthophosphate form the higher will be the fusion temperature and the greater will be the possibility of securing white fluffy ashes. On the other hand the more phosphorus in the metaphosphate form, the lower will be the fusion temperature and the greater the possibility of obtaining fused ashes.

The fusion temperatures of the meta-, pyro-, and orthophosphates were looked up in the literature in order to determine how the fusion temperatures of the flour ashes agreed with the fusion temperatures of the pure phosphates of which they were composed. According to data in the International Critical Tables potassium metaphosphate fuses at 800° C.,

potassium pyrophosphate, at 1090° C., and potassium orthophosphate, at 1340° C. The calcium or magnesium phosphates fuse at higher temperatures than the corresponding potassium phosphate. It thus appears that the mixture of phosphates in flour ash fuses at a lower temperature than any of its constituents. This is in accordance with the general metallurgical observation that the fusion temperature of a mixture of salts may be lower than that of any of its constituents alone.

Conclusions

Different flours may yield ashes of different characteristics even when ash determinations are conducted at the same temperature.

Flour ashes obtained under comparable conditions were classified into three different groups, white and fluffy, partially fused, and completely fused ashes. In these three types the potassium content is highest in the fluffy ash, lowest in the completely fused, and intermediate in the partially fused ash. The phosphorus content is lowest in the fluffy ash, highest in the completely fused, and intermediate in the partially fused. No orderly variation appears in the other constituents of flour ash.

Phosphorus in flour ash exists for the most part in the pyrophosphate form. Fluffy ashes contain small quantities of orthophosphates and fused ashes small quantities of metaphosphates.

When the time of incineration is 16 hours and the temperature 485° to 725° C., percentages of ash were obtained which agreed as closely as replicate determinations. When incineration was conducted at 750° C. the percentages of ash obtained appear to be low.

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THE POSSIBILITIES OF RESEARCH

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(Read at the convention, June 3, 1927)

When one speaks of research, the picture presented is usually that of a very highly scientific work, attended with innumerable long names. In speaking of the possibilities of research in the milling and baking industries, I wish to take a broader view, as I consider that any one who carries on any investigation be it in the laboratory, the mill, the bakeshop, or the wheat field, is a research worker.

The results of these investigations, added together, will advance these industries rather than the master researches of some great genius. Many millers and bakers have done good research work who do not consider themselves research workers at all.

At a meeting of the Pioneer section last winter one of the members made the statement that in using the experimental mill one experienced some of the romance of milling. He explained that by experimental milling he was able to learn something that no one else knew. He was doing research work, finding out facts concerning certain wheat that were unknown heretofore. He possibly never thought of it in this light, but it was research, nevertheless.

In the light of this experience, it seems to me that research work is possible to all of us. It need not be very wide in scope, but all new things are found by research and add their bit to the working knowledge in the two industries.

Research may be divided in several ways: First, the strictly scientific, wherein one works to find out facts purely to satisfy his thirst for knowledge. An example of such research is the study of

the properties of some one of the proteins, with no thought of practical application. Then there is the research started purely for the purpose of practical application. Such research might concern itself with the production of a bread improver, and might lead to a given process of bread making and patents could be obtained on the process. These two types of research are found in two different atmospheres; the first is usually found in the laboratories of our colleges and universities, the second is more sought after in our industrial laboratories, where the sole thought is always to lower the cost of production or to make a better quality of goods without increasing the production cost, or at least to hold the production cost below the increased margin which the improved quality will demand.

These two divisions of research are, it seems to me, very closely allied, inasmuch as the second cannot exist without the first. The chemist in industry is too prone to look upon the strictly scientific work as interesting but of no particular value, meaning that there is nothing in it which he can apply directly. However, let us remember that every research which results in practical application is made possible by the facts obtained by purely scientific research. If some one, by purely scientific research, had not determined the atomic weights of the elements, there would be no science of chemistry today. So let those of us who are at times engaged in purely industrial work acknowledge our debt to the pure scientist, who, without thought of fee or reward, unearths the facts which are later, perhaps, used by the industrial worker to evolve something new in a practical way.

Still a third class of research might be called the forced research: To illustrate, let us say some chemist finds the ash in certain flour running unduly high. He investigates, that is, he does some research work. He probably does not call it such, but that is truly what he is doing. He is going to find out something new, at least new to him and to the company which employs him. He finds out that the high ash is caused by impurities in the wheat, he makes an ash determination of these impurities and finds that the impurities are much higher in ash than is the wheat, the impurities are carried into the flour, because the wheat cleaning machinery will not take them out. He states his case to the people who manufacture wheat cleaning machinery. This starts research in the factory—the result in due time is machinery that will remove the impurities. A purer flour is the result. Progress has been made. In this connection let me point out that progress is

being made all the time by such minor researches. The want is created, the demand supplied.

Before taking up the subject of the possibilities of further research let us consider the present status.

By research we have determined some of the constituents of certain cereals. The determination of some of these constituents has become routine; namely, the determination of protein in wheat, and the determination of ash, moisture, and protein in flour. Other researches have been numerous; starch, the different proteins, the mineral salts, the fats, the enzymes, the acids occurring in cereals have all been investigated by many. Cereal Chemistry issues six copies a year, the greater part of which is devoted to the reports of such investigations. Our knowledge of the subject grows and by it new processes are evolved and more efficiency is obtained.

This work is going on so quietly that the progress is scarcely noticeable, but look back a few years. There was a time when Turkey Red wheat was considered too hard to mill, but the research work of certain progressive millers, who had a keen sense of observation, aided later by the chemist, evolved a system of wheat conditioning which puts this wheat in the front rank as a flour making wheat today.

The older millers who first undertook the milling of Turkey Red wheat probably did not consider that they were doing research work, but they certainly were, as they studied the effects of water, heat, and time upon this particular variety of wheat. They probably did not record their results in exact data, but were they not finding out something new, something that no one else prior to that time had been able to tell them? Was it worth while? Did it not make possible the use of this wheat, which is grown in a territory which is particularly adapted to the growth of this variety? This territory would probably have suffered economically had it grown other crops.

The time is not so far in the past but that all of us can remember the all-day long process of making bread.

Research has so identified the properties of the ingredients included in the dough batch, and evolved new ones, that today the process of bread making is a matter of only a few hours. Has it any value? Certainly, the cost of production is lowered, the shop machinery produces more, the capital required for the production of any given number of loaves has been considerably reduced.

Neither is the time in the far distant past when bread was not the nearly perfect food that it is today. Research told what should be included and the baker was quick to meet the demand.

Now, as to the possibilities of research, it is not necessary to say that they are great. In spite of all the fine work that has been done there is still plenty to do for all who feel so inclined. Again let me make it clear that in the industries which use cereals as their raw materials, research work is not confined to the chemist alone. The wheat breeder, the miller, the baker, the manufacturers of milling and baking machinery must all engage in research work.

At this point I will set forth some of the problems in the industries which I believe hold great possibilities for the research worker.

First, there is the problem of wheat breeding. We have as yet evolved no perfect wheat. There is still plenty of room for a wheat which will yield more bushels to the acre, will resist rust, will mature quickly, will have hardy characteristics, and will give a good yield of good quality flour.

The milling of wheat still holds many problems for the research worker, the proper methods of conditioning wheat, the proper breaking of wheat, the proper reduction of middlings, and the proper bolting are still subjects of research. It may well be that because of varying conditions of climate, temperature, and humidity and varying conditions of the wheat used, nothing can be evolved that will apply to all mills. In that case the problem becomes local, that is, confined to one mill, but the case is one for research, nevertheless.

Taking the broader view, we have all heard the statement made that probably the whole of the berry, within the bran coats, contained flour similar in characteristics were it only possible to separate it cleanly from the bran coating.

This presents a nice problem for research in which, perhaps, wheat breeders, millers, chemists, and machinery manufacturers could co-operate. The increased values in better yields and the lower cost of production through the saving in machinery would certainly be worth while. Let us not say that this is impossible. Remember, some of our most useful inventions were given us by men who didn't know that it could not be done.

The by-products of milling—the bran and the shorts—are today considered as stock food and sold as such. Are there in these products any constituents which could be put to a better use and at a greater profit? Another problem for the research worker.

A great amount of research has been carried out in the baking industry. These researches have been divided into two classes. One concerns itself with the nutritional value of bread; the other with improvements in the bread making process.

The first class of research has taught us the actual food value of bread. These researches have resulted in use of milk, malts, and mineral salts in the dough batch in order that bread might be made a more nearly perfect food. The field of nutritional research is still open. It has by no means been exhausted.

The second class of research in the baking industries has concerned itself with the process of making bread. I have already pointed out that the time of this process has been greatly reduced. Better and more powerful yeast strains, a knowledge of the action of sugars, malts, salts, and other ingredients added to the dough have contributed to this result. Another factor contributing to this result has been a study of fermentation.

This brings me to a point where this discussion can be greatly narrowed to a point of great interest to all cereal chemists and to the industries as a whole.

What about fermentation? In the last few years the statement has been made by chemists that any sound, well milled flour, could be baked into satisfactory loaves of bread. It was recognized that while the percentage of patent would affect somewhat the crumb color of the bread, and that the absorption would vary with the fineness of milling and the colloidal character of the proteins and starches, nevertheless by careful control of fermentation or by the addition of acids and salts, all sound flours were capable of being baked into good loaves of bread not unlike in quality.

Others, while admitting that every flour has a period of fermentation at which the best bread can be made, still insist that quantity of proteins and the inherent qualities of these proteins are important factors which make one flour better than another. Practical bakers are also divided on the question. Some bakers claim that by carefully controlled conditions they are able to make a quality loaf from flour which is well milled and sound but is not high in protein content. Other bakers pay premiums for flour of the higher protein contents and claim that they are well repaid by the improved quality of their loaf and the increased assurance attending its use.

Here are some problems for investigators in cereal chemistry, some questions to be answered:

1. Has the gluten of wheat flour inherent properties?

2. Are these properties capable of being altered during fermentation?
3. Are they altered by constituents contained in the flour itself during the process of fermentation?
4. Can these properties be altered by the additions of acids and salts?
5. Can these properties be altered by the use of enzymes?
6. Can these properties be altered by mechanical means during the dough mixing process?

I find it rather hard right here to express myself as I would like to do. A well known member of this association recently remarked to me, that what is most needed by this association is a vocabulary, so that different members when in discussion would not seemingly be in disagreement, when as a matter of fact they were in agreement.

The question I am trying to ask is this: Are the protein bodies in wheat flour fixed and unalterable or is the baker master of the situation? Can he bend the properties of these protein bodies to his will? By the careful control of fermentation, or by the additions of acids or salts, or by the use of enzymes, or by mechanical means can he bring the quality of the gluten in his dough batch to a point simultaneous with sufficient gas production to produce a quality loaf of bread from his dough? Are flours low in protein capable of producing a loaf of bread just as high in quality as flour stronger in protein, when both are given the correct absorption and fermentation?

An affirmative answer to these questions would mean much to the economy of the nation as a whole. A negative answer will put an ever increasing amount of work on the wheat breeder and agricultural expert.

I have gone to some length in stating these problems, perhaps because they are most interesting to me. Also because research workers have reported on some phases of these problems. Also because some have already made their decisions and these decisions are opposed to one another.

The field is still open—to deal with the researches that might be attempted is beyond the scope of this paper.

So let me end with the same thought with which I began. The further progress of the milling and baking industries depends on the possibilities of research. Every miller, every baker, every cereal chemist, every manufacturer of milling and baking machinery who investigates and adds a little to our knowledge of these industries is a research worker, and has his part in that progress.

PROBLEMS OF THE NON-FLOUR CEREAL CHEMISTS

By CARL MINER

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(Read at the convention, June 2, 1927)

If there is any one fixed and immutable fact in regard to the diet of ourselves and our fellow countrymen, it is that we prefer to take the cereal portion of our food in the form of wheat bread. Even the colossal attack on this food habit during the war had a merely evanescent effect which scarcely outlasted the war itself. All the elaborate efforts of chemists, doctors, dietitians, biologists, advertising experts, professional spellbinders, and other myrmidons of the food administration failed utterly to effect any permanent change in the quantity or quality of cereals in the diet.

Wheat flour still ranks, as it did before the deluge of propaganda, "first" with no "second"—roughly, four-fifths of our grain food. We therefore must recognize that in considering the problems of non-flour cereals, we are dealing with questions which, judged from the standpoint of cereal chemistry in general, are of relatively small importance. Yet when we consider that in this country the corn crop alone furnishes sufficient calories to supply the total calorific requirements of the nation twice over, we are compelled to admit the fundamental importance of the non-flour cereal products.

The basic commodities on which human prosperity depends are hours, acres, and power, and the problem of the cereal chemist, as of the rest of mankind, is to produce a maximum of utilities for the human race with a minimum expenditure of these three essentials. No one of us, I suppose, has any doubt about the basic extravagance of a system which uses 100 calories of corn to make 24 calories of pork, and to any one who has such doubt, I recommend an earnest perusal of Armsby's "Cost of Roast Pig," which so cogently compares that method of producing human food to the original plan recorded by Charles Lamb of roasting a pig by burning a house. I am not appearing as a proponent of vegetarianism, but I am urging upon the cereal chemists as a group the economic soundness of the effort to utilize cereal food *per se* rather than in the form of meat, so far as that can be done without sacrifice of physiological well being; that is, it seems to me justifiable to as-

sume that the food which is cheapest (in the sense of the hours, acres, and power necessary to produce it) should be used as far as possible and that the burden of proof, therefore, is on those who would displace cereals in the diet.

First, then, among cereal problems, I should rank that of producing palatable foods from corn for, deplore it as we may, palatability is the primary test by which the human diet is selected now just as it always has been. One corn food of importance has already been developed in addition to the merely milled forms, such as cornmeal and hominy, that is Corn Flakes, of which a very large quantity is now produced. In addition, an enormous tonnage of corn is turned into the corn products starch, oil, glucose, and sugar. The last named of these—corn sugar—which as now produced is practically chemically pure dextrose, is making a bid for the sugar market and is already beginning to replace cane sugar for certain uses where sweetness is not the primary requisite.

Despite the fact that many million bushels of corn are devoted to these and other food uses, the total used directly for human food amounts to but an insignificant fraction of the annual corn crop and the problem of perfecting a corn food that will tickle the human palate is one that offers fame and fortune to the cereal chemist.

Wheat bread and the products of the biscuit and cracker industry, are characterized by the fact that they belong to the ready-to-eat class of food, whose popularity has increased in inverse ratio to the size of our kitchens. The outstanding disadvantage of the cereal foods that compete with them is that they require a comparatively long cooking period in the kitchen rather than in the factory. This is not true of a few of them—corn and wheat flakes, puffed grains, shredded wheat, and the like, but of the so-called breakfast cereals and macaroni, it is all too true. Recent years have seen a more or less successful effort to reduce the cooking periods necessary for breakfast cereals. The change, however, has been mainly in the reduction of the particle size of the cereals and has resulted merely in making them more rapidly permeable by heat and moisture during the cooking process. In many cases claims which are made for quick-cooking cereals, that they are precooked, are absolutely without justification, as no detectable change has taken place in the starch granules and so far as I am aware no genuinely precooked food designed to be eaten hot has been put on the market. The whole question of what constitutes "thoro," or "perfect," or "complete," or "satisfactory" cooking of a cereal is chaotic. As

such raw starches as those in our ordinary cereals are digested completely by the human body, the primary question, except in the case of invalids or infants, is probably not digestibility but palatability, and it is on palatability alone, I suspect, that the cooking directions for most of the cereals, quick-cooking and otherwise, are based. The effort to formulate a definition of "the perfectly cooked cereal" on the basis of scientific literature is fruitless, for no data are available on which such a definition properly can be based.

Now, the ultimate ideal of a quick-cooking cereal is one that can be prepared for the table by applying the Campbell's soup directions—"add hot water and serve." The manufacturer who first produces a breakfast cereal which is highly palatable and which, when cooked according to that simple and speedy method, will be brought to its maximum digestibility, will have a gold mine. As a foundation for the attack on this problem we need first a method of determining when a cereal is cooked to the point of maximum or optimum digestibility; and second, a quick means of comparing the degree of cooking of cereal products. Neither of these methods is available at present and both must be developed if we are to solve the problem of producing quick-cooking cereals.

The problem of determining when a cereal is cooked to the point of *optimum utility* as human food is a tremendously complex one, but the problem of determining the point at which cereals are sufficiently cooked to be *satisfactory* for use as human food is probably comparatively simple. Essentially, it consists in arriving at a conclusion in regard to the cooking period necessary in the case of one cereal and then developing a chemical test by which the degree of cooking of the starches of various cereals variously cooked can be compared. Until we reach such a point we shall continue in the present unfortunate condition in which the process of improving the rate of cooking of a cereal may consist merely in changing the directions on the package, for today there are neither standards for determining the necessary degree of cooking of starchy foods nor any methods of importance for comparing degrees of cooking of such foods.

Another need of the industry is a method of preventing rancidity in cereals, especially precooked cereals. We try to do it now by taking the oil out as completely as possible but this is neither desirable from the standpoint of food quality nor wholly successful even at its best. Other means are undoubtedly available. A chemist

in the soap industry has found that the addition of a very small amount of diphenylamine to soap successfully prevents rancidity even in soaps whose keeping quality is otherwise very unsatisfactory. It seems highly probable that the underlying theory of this invention can be applied successfully to the prevention of rancidity in cereal foods, and the problem should be attacked on both that basis and others.

The weevil and his cerealivorous kin are always with us. Some further progress has been made latterly in controlling them in the mill by means of chlorpicrin, which appears to be reasonably efficient against insects and less dangerous to human life than cyanide. No method has been perfected, however, which enables us to seal a sterile cereal in a sterile package with absolute certainty, at least in the case of products such as pancake flour not suited to heat treatment. A few years ago, a method of sterilizing the cereal and package after sealing by means of an electric arc was tried out in some plants and showed great promise, but the machine has never been perfected, or at least, it has not been placed on the market. The problem of producing package cereals that are free from insect life is still in the cereal chemist's list of unfinished business.

Of the more strictly chemical problems the study of the starch granule stands preeminent in importance. Alsberg's researches have added greatly to our knowledge in recent years. Yet much remains to be done and relatively little work is being undertaken in this field.

Chemical differences between the vegetable and animal proteins have by no means been completely worked out and their importance is obvious, as on them depend those biological differences which appear to exist between these two types of nitrogenous foods. In view of recent contributions to our knowledge of nutrition, it appears far from definitely proved that any such difference actually is inherent in the protein itself and until feeding tests have been made in which the protein fraction of the ration consists only of pure chemical compounds derived respectively from animal and vegetable sources, this question cannot be said to have been finally settled.

There are many questions for whose final solution we must depend upon our biological chemists and some of these problems are being vigorously attacked at this time. For example, within the last few years the English chemist, Mellanby, has announced the

discovery of the presence in cereals of a prorachitic factor which he has christened "toxamin." His results have not been corroborated by other workers nor have they been generally accepted as finally proved to the satisfaction of the scientific world. They have, however, been given wide publicity in England. Steenbock, whose work on vitamin D, especially on the irradiation of foods, is well known to you, reported at the recent mid-west regional meeting of the American Chemical Society, in Chicago, that he had repeated many of Mellanby's experiments and had performed many others designed to test the validity of the toxamin theory, but without finding any evidence whatever in support of it—his conclusion seemingly being that the rachitic effect of an excess of cereals in the diet is due to absence of vitamin D and perhaps to improper balance or insufficient quantity of one or the other of the bone-forming elements.

After all, the real problem of the cereal industries is to learn exactly what are the deficiencies of the cereals and how these deficiencies can best be overcome. The cereals are among the cheapest of our foods and it is to our advantage as members of the human race to learn how to feed ourselves in the most economical fashion possible. Feeding grains to a cow to produce milk is merely one way of supplementing deficiencies of these grains to make them more satisfactory as human food. It may not be by any means the most efficient way of improving these grains. If we knew exactly what amino acid or other component or components the protein of corn lacked to make it as efficient biologically as milk protein, we might find a much more economical way of supplying this deficiency than by feeding the corn to a cow.

Today, our rapidly increasing knowledge of proteins, of vitamins, and of mineral nutrition suggests the proximity of that day when the biological chemist will be able to tell us in terms of chemical compounds just what the cereals lack, and when the organic synthesist will be able to show us how to prepare these compounds more cheaply than by the natural processes of animal nutrition. When that time comes it will be the function of the chemists of the cereal industries to translate all these results of research into terms of industrial utility and human welfare and to substitute the operations of the cereal plant for the time honored methods of the dairy, the poultry farm, and the hog pen.

RELATION OF WATER ABSORBING CAPACITY OF FLOUR TO PROTEIN CONTENT, BAKING QUALITY, AND LOAF WEIGHT

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The water absorbing capacity of flour is considered an important property by the commercial baker. Water absorption is of particular importance to the baker, as it influences the yield of baked product.

Jago (1911) calls attention to the importance of water absorbing capacity of flour in governing the yield of bread, and the use of water absorbing capacity for judging other qualities of flour. Mangels and Sanderson (1925) have shown that no correlation exists between water absorbing capacity and the test weight of the wheat from which the flour was milled.

Water Absorption and Protein Content

It is generally thought that strong high protein flours will show a high water absorbing capacity. Flour milled from hard high protein wheats will usually show relatively high water absorbing capacity, but considerable variation in both water absorbing capacity and protein content may be found in hard wheat flours milled from different lots of wheat.

Table I shows correlation coefficients between the percentage of water absorbed and the protein content. The flours were milled on the experimental mill at the North Dakota Experiment Station, from samples of hard red spring wheat. The coefficient of correlation is positive for 1923, 1924, and 1925, but is negative for 1926.

The 1926 crop was high in protein content, and Table I shows that 273 samples of straight grade flour milled from this crop averaged 13.73% protein. The 1926 crop suffered from extremely dry weather; the relation between protein and absorption, therefore, is abnormal, but this is in line with other peculiarities of this crop.

TABLE I
CORRELATION OF WATER ABSORBING CAPACITY OF FLOUR AND PROTEIN CONTENT
(Straight grade flour milled on experimental mill)

Year	No. of samples	Mean absorption	Mean protein content	Coefficient of correlation	Probable error
		%	%		
1923	217	59.0	13.01	0.236	0.043
1924	297	57.8	11.84	0.222	0.037
1925	262	59.4	12.61	0.275	0.038
1926	273	58.7	13.73	0.095	0.040

The positive correlations for the other three years are between 0.2 and 0.3. Coefficients of this magnitude do not indicate a high degree of correlation between protein content and water absorption of flour.

Water Absorption and Loaf Volume

Loaf volume is considered the best index of baking strength. Table II shows correlation between the percentage of water absorbed and the loaf volume. The coefficients of correlation, as in case of protein and absorption, are positive for 1923, 1924, and 1925, but negative for 1926. The coefficients between loaf volume and absorption show greater variation than those between protein and absorption.

The positive correlations show variation from 0.133 to 0.332 and do not indicate a high degree of correlation.

TABLE II
CORRELATION OF WATER ABSORBING CAPACITY OF FLOUR AND LOAF VOLUME
(Straight grade flour milled on experimental mill)

Year	No. of samples	Mean absorption	Mean loaf volume	Coefficient of correlation	Probable error
		%	cc.		
1923	217	59.0	2352	0.133	0.044
1924	297	57.8	2145	0.191	0.037
1925	262	59.4	2108	0.332	0.037
1926	273	58.7	2195	0.096	0.040

Absorption and Loaf Weight

The influence of absorption on loaf weight or yield of bread is of real economic importance to the baker. Table III shows coefficients of correlation between the percentage of water absorbed and the weight of the baked loaf. The correlation coefficients are positive and greater than 0.5 in all cases. A marked correlation, therefore, exists.

In making these tests, the same amount of flour was used for each loaf. The loaves were baked at the same temperature and for the same time. The weight of loaf, therefore, indicates the water-

holding capacity of the flour when baked into bread. The water absorbing capacity of flour is an index of the yield of baked bread obtainable from a given weight of flour.

It will be noted that the highest coefficient of correlation is found for the 1926 crop. The 1926 crop averaged high in protein content, owing to extreme drouth. The 1923 crop flours averaged 13.01 per cent protein as compared to 13.73 for 1926 crop, but the lowest coefficient in Table III is 0.593 for the 1923 crop. The high protein content of the 1923 crop was due to heat rather than drouth. With the exception of the 1923 crop, the coefficient of correlation between absorption and loaf weight varies directly as the average protein content of the flour samples. This indicates that the retention of water during baking is dependent on the properties and quantity of protein in the flour.

TABLE III
CORRELATION OF WATER ABSORBING CAPACITY OF FLOUR AND LOAF WEIGHT
(Straight grade flour milled on experimental mill)

Year	No. of samples	Mean absorption	Mean loaf weight	Coefficient of correlation	Probable error
		%	gm.		
1923	217	59.0	475	0.593	0.029
1924	297	57.8	482	0.652	0.022
1925	262	59.4	489	0.795	0.015
1926	273	58.7	483	0.863	0.010

Summary

1. A positive correlation between water absorbing capacity of flour and protein content is found in three of four years studied, but the degree of correlation is low.

2. A positive correlation between water absorbing capacity of flour and loaf volume is found in three of four years studied, but the degree of correlation is lower than that found between protein content and absorption.

3. A high correlation between water absorbing capacity of flour and loaf weight is found for four crop years. The correlation coefficient in all cases is greater than 0.50.

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1925 Correlation of test weight per bushel of hard red spring wheat with flour yield and other factors of quality. Cereal Chem. 2:365-369.

BOOK REVIEW

D. W. Kent-Jones, *Modern Cereal Chemistry*, revised and enlarged edition, 446 pages. The Northern Publishing Co. Ltd., Liverpool, England, 1927.

The hazards involved in the use of the term "modern" in these rapidly moving times are well illustrated by the differences in the two editions of Kent-Jones' book. The second edition is not only one-third larger than the first (1924), but includes omissions from, as well as additions to the first edition. These changes appear in the first chapter, and continue through the entire volume. Chapters II and VII have been added.

Chapter I contains new material, particularly in the form of tables of wheat composition. It seems regrettable that the author did not draw data from other sources than his own laboratory, particularly concerning American wheats, which are not adequately represented. Chapter II received a new and more comprehensive title, "Nutritive value of bread," in the revision. It now includes a discussion of bread constituents other than vitamins and thus gives a more rational and adequate picture of the position of bread in a balanced human dietary. Chapter III covers the chemical composition of rye, barley, oats, maize, and rice products.

The first part of Chapter IV, on colloidal chemistry, is similar to the first edition but the last part has been substantially revised. Hydrogen-ion concentration is discussed in Chapter V from the standpoint of principles and methods.

The chapter on Strength and the Colloidal Chemistry of Flour has been practically rewritten. It contains less detail quoted from papers by other investigators than the earlier edition and develops this difficult subject in a more coherent fashion. Chapter VII, Chemistry of the Baking Process, is an addition to the book, and treats this subject in a rational manner, considering the state of our present knowledge. The Composition of Mill Products is presented in Chapter VIII, and data are more extensive than in the first edition. In Chapter IX, on Bleaching and Flour Improvers, the controversial aspects of the subject are discussed in the light of the Report of the Department Committee (England, 1927).

The first portion of Chapter X, on Conditioning, again contains statements which the reviewer regards as speculative. The author has added a concise review of his recent paper (see *Cereal Chemistry* 4:72) on the heat treatment of wheat. Chapter XI, details the considerations involved in the determination of moisture in wheat and flour. The reviewer feels that the selection of material for this discussion is not well balanced, and that too much space is given to certain studies, while no reference is made to the excellent work of Spencer, and Mitchell and Alfend. Fornet, Chopin, Liese, Bidwell and Sterling, and others are not mentioned.

Chapter XII describes numerous analytical methods. The sections dealing with gluten, and protein determinations have been amplified and new material relating to the separation and estimation of the protein fractions has been added. In addition to changes in other sections, the modification of the discussion of H-ion concentration should be mentioned. A new section on the color estimation devised by Kent-Jones and Herd appears in this edition. Chemical leavening agents receive more consideration than in the former text. A selected bibliography of about 230 titles has been added.

The book is unique and fairly comprehensive, altho it tends to exploit the author's personal views and the processes developed in the laboratory to which he is attached.

C. H. Bailey.